AQUAPONICS: THE INTEGRATION OF FISH AND VEGETABLES CULTURE IN RECIRCULTING SYSTEMS

BY

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1. INTRODUCTION

Population of Egypt is gradually increasing and there is a necessity to find out new techniques to reduce the gap between population needs and agricultural production. One of the new techniques called "aquaponics" is which we can utilize the outputs of fish farming in growing vegetables, i. e., lettuce, cucumber, tomato, cabbage and so on. In this technique a minimum requirements of nutrients could be used, furthermore removal the fish feces.

Aquaponics is the integration of aquaculture (fish farming) and hydroponics (growing plants without soil). In aquaponic system the fish consume food and excrete waste primarily in the form of ammonia. Bacteria convert the ammonia to nitrite and then to nitrate.

Aquaponics has several advantages over other recirculating aquaculture systems and hydroponic systems that use inorganic nutrient solutions. The hydroponic component serves as a biofilter, and therefore a separate biofilter is not needed as in other recirculating systems. Aquaponic systems have the only biofilter that generates income, which is obtained from the sale of hydroponic produce such as vegetables, herbs and flowers **(Rakocy and Hargreaves, 1993).**

Small proportion of ammonia is toxic to fish, when as nitrate is not toxic to fish. If nitrate increased over a specific limit it will be toxic to fish eaters (human being) and cause nitrate pollution and the eaters will suffer from methamoglobnia disease. The blood of the affected people became brown and will not be able to carry oxygen to the rest of human organs **(Tuker and Boyed, 1985)**. To avoid this problem in aquaculture, part of water should be discharged daily and add fresh water instead. Another solution to this problem is establishing hydroponic system attached to the aquaculture and cultivates plants in the hydroponics in order to save discharged-water and gets use of existing nitrate.

Benefits of aquaponics are conservation of water resources and plant nutrients, intensive production of fish protein and reduced operating costs relative to either system in isolation. Water consumption in integrated systems including tilapia production is less than 1% of the required in pond culture to produce equivalent yields **(Rakocy, 2002).**

Lettuce is one of the best crops for aquaponic systems because it can be produced in a short period and, as a consequence, pest pressure is relatively low. Unlike tomato and cucumber, a high proportion of the harvested biomass is edible. With lettuce, income per unit area per unit time is very high. Other fast growing and high income generating crops are herbs such as basil and chive, which are being grown commercially in aquaponic systems **(Rakocy and Hargreaves, 1993)**.

The objective of the current investigation was to study the possibility of producing lettuce plants depending on the nutrients exited in effluent fish as compared with the lettuce production using standard nutrient solutions.

2- LITERATURE REVIEW

2.1. Aquaponics

Recirculating aquaculture – hydroponic system was developed to illustrate one of the many engineered production systems used in modern agriculture. The system provides an artificial, controlled environment that optimizes the growth of aquatic species and soil-less plants, while conserving water resources. In this system, fish and plants are grown in a mutually beneficial, symbiotic relationship **(Johnson and Wardlow, 1997).**

Aquaponics is a combination of aquaculture and hydroponics, two systems that are not new, but share a common problem and concern, toxic water buildup. In aquaculture, it is the fish emulsion, with hydroponics, it is fertilizer water. This toxic water is not good for the fish or the plants. This water must be cleaned from time to time and it cannot be dumped any place in our environment without causing damage **(Bromes, 2002)**.

Aquaponic systems are recirculating aquaculture systems (RAS), which produce both fish and plants. The simultaneous production of fish and plants is possible because the system requirements for growing fish are very similar to those required for growing plants. RAS's are designed to raise large quantities of fish in relatively small volumes of water by treating the water to remove toxic waste products and reusing the treated water. During the continual process of treatment and reuse, non-toxic nutrients and organic matter accumulate in the water. These metabolic by-products are potentially valuable and can be used to grow plants **(Rakocy, 2002).**

Plants grow rapidly in response to the high levels of dissolved nutrients that are either excreted directly by fish or generated from the microbial breakdown of fish wastes. In RAS's that have daily water exchanges of less than 5% the accumulation of dissolved nutrients approaches the concentrations found in hydroponic nutrient solutions. Nitrogen, in particular, can occur at very high levels in recirculating systems. Bacteria convert ammonia to nitrite and then to nitrate. Ammonia and nitrite are toxic to fish, but nitrate is relatively harmless and is the preferred form of nitrogen by higher plants, such as fruiting vegetables. It is symbiotic relationship between fish and that makes the consideration of an aquaponic system a reasonable system design criteria **(Rakocy, 2002).**

Aquaponics is a bio – integrated system that links recirculating aquaculture with hydroponic vegetable, flower, or herb production. Recent advances by researchers and growers alike have turned aquaponics into a working model of sustainable food production. In aquaponics, nutrient wastes from fish tanks are used to fertilize hydroponic production beds via irrigation water. This is good for the fish because plant roots and associated rhizosphere bacteria remove nutrients from the water. These nutrients generated from fish manure, algae, and decomposing fish feed are contaminants that would otherwise build up to toxic levels in the fish tanks, but instead serve as liquid fertilizer to hydroponically grown plants. In turn the hydroponic beds function as a biofilter so the water can then be recirculated back into the fish tanks. The bacteria living in the gravel and in nutrient cycling; without these microorganisms the whole system would stop functioning (**Diver, 2000; Selock, 2003; Lee, 2004).**

Aquaponics is the combination of hydroponics (the growing of plants without soil) and aquaculture (the growing of fish in a recirculating system). In aquaponics, nutrient waste from fish tanks are used to fertilize hydroponic production beds via irrigation water. This is good for the fish because plant roots and associated rhizosphere bacteria remove nutrient from the water. These nutrient, generated from fish manure, algae and decomposing fish feed, are contaminants that would otherwise build up to toxic levels in the fish tanks, but instead serve as liquid fertilizer to hydroponically grown plants. When one looks at the environment as a whole, the fish and plants represent a model for the recycling of basic elements in the environment. Thereby aquaponics provides excellent hands- on activities to learn about science, math and technology and how it relates to their environment **(Okimoto, 2004).**

Aquaponics is simply the combination of aquaculture (fish farming) and hydroponics (growing plants without soil). In a symbiotic relationship, the fish provide nutrients necessary for plant growth. And the plants, in taking up the nutrients, help to clean the water the fish live in. An aquaponic system is a mini ecosystem where both plants and fish thrive **(Karen, 2005).**

Aquaponics is simply the combination of recirculating aquaculture (intensive culture of fish) and hydroponics (growing plants without soil). In aquaponic system fish culture consumes food and excretes waste, primarily in the form of ammonia. Bacteria convert the ammonia to nitrite and then to nitrate, which the plants consume **(Nelson, 2006a, b and c).**

Aquaponics system consists of two main components:-

I-Hydroponics

II-Aquaculture

2.1.1. Hydroponics

The world hydoponic was introduced by **Gericke (1937)** and subsequently adopted by Gericke to describe "Crop production in liquid culture media" this original concept still finds support. In the recent publication by **Douglas (19985)** under the title "Advanced guide to hydroponics", Crop production without soil was divided into hydroponics or water culture and media culture, the latter including both organic and inert substrate. Such as a classification is both logical and historically based. Nevertheless the popular impression of hydroponic crop production now generally includes gravel and sand culture.

Hydroponics is a technology for growing plants in nutrient solution (water and fertilizers), with or without the use of an artificial medium (e. g. sand, gravel, vermiculite, Rockwood, peatmoss, sawdust) to provide mechanical support. Liquid hydroponic systems have no other supporting medium for the plant roots; aggregate systems have a solid medium of support. Hydroponic systems are further categorized as open (i.e., once the nutrient solution is delivered to the plant roots, it is not reused) or closed (i.e., surplus solution is recovered, replenished, and recycled) **(Jensen, 1989)**

Hydroponics is perhaps the most intensive method of crop production in today's agricultural industry. It uses advanced technology, is highly productive, and is often capital – intensive. Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures that give control of air and root temperature, light, water, plant nutrient and protect against adverse climatic conditions. While most greenhouse horticultural crops are grown in soil, the last 12 years has produced an avalanche of reports in hydroponics. There are many types of hydroponic systems as well as many designs of greenhouse structures and methods of control of the environment there in. Not every system may be cost effective in any location. The future growth of hydroponics depends greatly on the development of systems of production competitive in cost with systems of open field agriculture **(Jensen, 1989).**

Fumiomi (1997) mentioned that hydroponic is the method of growing plants in nutrient enriched water solution without the benefit of soil. Since plant food and water are delivered directly to the roots of the plants energy normally used by the plant to find these elements through root growth is redirected in to upward green growth and fruit production. When properly maintain, hydroponically fed plants grow and produce faster than their soil grown counter parts. In addition, since root systems do not compete for the food supply, more plants can be grown in a smaller space.

Most hydroponic systems consist of a nutrient reservoir, a growing tray, a method for delivering the food and water to the roots, such as a pump or wick, and the substitute medium used in place of soil. Since root systems don't expand to provide plant support, trellising of many plants is necessary. The hydroponic method has several other advantages over soil-grown plants. Hydroponic systems recycle their nutrient solution for use in the next watering cycle, reducing fertilized waste, run-off and conserving water. Nutrients can be more precisely measured and altered to meet a plants changing need based on weather conditions and other variables. Pest control measures are reduced by eliminating one of their most common breeding grounds, soil and since hydroponically grown root systems are not competing with each other for nutrients and water, more plants can be grown in a smaller space.

2.1.1.1. Advantages of hydroponics:-

Cooper (1979) Wrote that the development of hydroponic or NFT is considered as one of the modern techniques that lead to promoting and supporting the food production. However, even in this relatively short period of time it has adapted to many situations especially where water as scare. It has the potential ability to reduce the water consumption of outdoor crops to very low levels, not just because it eliminates the normal losses of water by drainage and evaporation, but also because it is the only method of agriculture production that can reduce water consumption to the essential water loss through the leaves of the plants.

Johnson (1979) reported that hydroponics is a plant-feeding method in which all constituents of normal soil-root environment are absent except water, inorganic salts, and air. There are contain advantages to hydroponic culture. It provides several problems often encountered in conventional culture: poor soil structure, poor drainage and nonuniform texture, weeds, and (with proper sanitation practices) pathogenic soil organisms. Automated controls used in hydroponic culture reduce some of the management decisions on amounts and timing of fertilization and irrigation but force the grower to face other. For instance, the hydroponic grower must substitute for “mother nature” and help keep in balance all of the chemical, physical systems which aid plant growth. Hydroponics provides less buffering action to maintain the needed PH or acidity-alkalinity ratio. It is up to the grower to do this and also control the availability of plant nutrients. No clay particles or organic matter are present to store and gradually release plant nutrients, and one must avoid accumulation of toxic elements in the solution. The water-holding capacity of groveler sand system is exceedingly small compared to soil, and therefore power is required to pump water to the plants. Malfunctions in the system will result in rapid wilting and potentially serious plant stress effects. As, hydroponic systems lack soils wide range of micro-organisms that can art as antagonists and suppress soil-borne pathogens. While soilless systems are generally free of diseases initially, they can be infected readily and serious plant losses can occur.

Jensen (1981); Resh (1981) and Benoit (1987) stated that the advantages of the nutrient film technique in glasshouse crop production are:-

a- Low capital cost.
b- Elimination of soil sterilization and preparation.
c- Rapid turnaround between crops.
d- Precise control of nutrient.
e- Maintenance of optimal root temperature by heating of the nutrient solution (77 F for tomatoes, 84 F for cucumbers).
f- Simplicity of installation and operation.
g- Reduction of transplanting shock by use of growing pots or cubes and preheating of nutrient solution to optimal root temperatures.
h- Easy adjustment of nutrient solution formulation to control plant growth under changing light conditions.
i- Use of systemic insecticides and fungicides in the nutrient solution to control insects and diseases of ornamental crops.

j- Possible energy saving by keeping the greenhouse air temperature at lowers than normal levels due to maintenance of optimal root temperatures.

k- Elimination of plant water stress between irrigation cycles by continuous Watering.

l- Conservation of water by use of a cyclic system rather than an open system.

Benoit (1987) add the following advantages of NFT in particular:

-More direct control of the root medium as no account is to be taken of the more or less inert capacity of the substrate; a method of growing that is ecologically sound, because the problem of substrate waste (50to 100m/ha) is eliminated and there is no need for disinfection either; moreover in substrate culture an eutrophication of the mats, giving a drainage of 20% of the applied nutrient solution.

2.1.1.2. Disadvantages of hydroponics:-

Cooper (1979) said that when the idea of the nutrient film technique use first being tried out, the sceptics, who were then in the majority, put forward as one of the reasons why NFT cropping was impractical the statement that “A disease organism will enter one channel and will be spread throughout the system by the recirculating solution and the whole crop will rapidly be wiped out”. Because of this it was argued that the risk would be far too great for it to be acceptable to any commercial enterprise.

Johnson (1979) clarified that the most important disadvantage is that this method of plant growing is more costly than soil culture because of the specialized equipment required. Soilless culture is justifiable only where plants must be grown in the absence of good soil. Where soil-borne diseases are not controllable, or perhaps on the basis of personal interest.

Jensen (1981) summarized the disadvantages of hydroponics as follows:-

a-The original construction cost per acre is great.

b-It needs experience in the growing operation, knowing of how plants grow and the principles of nutrition are important.

c-Introduced soil-borne diseases and nematodes may be quickly spread to all beds on the same nutrient tank of a closed system.

d-Most available plant varieties have been developed for growth in soil and in the open. Development of varieties adapted to controlled growing conditions will require research and development.

e-The reaction of the plant to good or poor growth is unbelievably fast. The grower must observe his plants every day.

2.1.1.3. Types of soilless culture:-

Douglas (1985) mentioned that soilless culture including three main systems according medium culture:-

I- Sand culture.

II- Aggregate culture.

III- Water culture.

a- Sand culture:-

The essential feature of this type of system is that the substrate should retain sufficient moisture for plant growth yet be adequately drain to ensure proper aeration in the root zone. This requirement is not always easy to achieve; aeration can be less efficient than in classed (re-circulating) system owing to the finer particle size and the less frequent irrigation to carry oxygen in solution. In practice, depending on the climate and stage of growth **(Steiner, 1976b).**

The traditional material for construction of permanent troughs or bed for sand culture is concrete, coated with an inert paint or epoxy resin to protect it from the slightly acidic nutrient solution. Other construction materials include fiberglass, plywood coated with fiberglass, timber coated with asphalt and asbestos sheet. For cheapness, polythene sheet (at least 0.1 mm thick) may be used **(Collins and Jensen, 1983)**

b- Aggregate culture:-

The central feature of this type of system is a set of watertight troughs or beds, filled with a coarse, inert aggregate to provide easy flow of solution. The particle size is usually quoted as greater than 3mm diameter**(see Steiner, 1976);**7.5 mm gravel,” free of fines”, was recommended by**(Schwarz,1986).** The beds are flooded periodically with nutrient solution, the latter draining out and being returned to the catchment tank.

c- Water culture:-

The essential feature of water culture is that the roots of the plant are wholly or partially immersed in the nutrient solution, which may be static or circulating continuously.

Water culture was divided to:-

I-Gericke's System.

The first system for commercial crop production without soil to attract world-wide attention was that developed by **(Gericke, 1929, 1937, 1938)**, working at the California Agricultural Experiment Station. In his first publication Gericke briefly described a system of troughs approximately 0.6m wide 0.25cm deep and 10m in length, constructed from bituminous roofing paper. Troughs used subsequently were variously constructed of concrete (coated with non-toxic water-resistant paint), wood, and iron sheet and certain asphalt preparations. The seedbed supported on netting above the trough was a mat of vegetable material such as straw, sawdust or peat moss. In addition to supporting the young plants, the seed bed excluded light and thus prevented algal growth

II- Floating Hydroponic Systems.

As indicated in the title, floating hydroponics is a form of water culture in which the plants are supported above the surface of the solution on 'raft' of lightweight plastic material, expanded polystyrene being the obvious choice. This ingenious concept overcomes one of the major problems encountered by Gericke, namely that of mounting the plants above the solution **(FAO, 1990).**

An experimental installation of this type was described by **(Massantini, 1976).** The bed, 1.01m wide, 3m long and 15m deep, was made of timber lined with plastic film, and the floating panels were 1m square and 2cm thick. The nutrient solution was recirculated, with aeration controlled by a timber. The crops grown experimentally were lettuce, chard and strawberry. Located in 15mm diameter holes at suitable spacings in the supporting rafts.

III- Deep Re-circulating Water Culture.

Modern systems of deep water culture, designed to overcome the problems encountered earlier in Gericke's system, are currently being used in Japan to produce tomato, cucumber, salad and other crops. Japan has a particularly large greenhouse industry, amounting to 27,079 ha in 1977 **(Shimizu, 1979).**

IV- Nutrient film technique (NFT):-

The nutrient film technique, generally referred to as "NFT", is a novel system of water or solution culture characterized by using only a very shallow stream of solution flowing down the troughs or gullies, the plant roots form a more or less thin mat over the base of the gully, approximating to a 2-dimensional rather than the usual 3-dimensional root system. The primary purposes for this shallow layer of the plants above the solution with only their roots immersed. Is avoided. The solution is kept so shallow that the young plants, in their propagation blocks or pots, can simply be stood in the gullies, the roots rapidly emerge into the flowing liquid. Secondly, the high ratio of surface area to solution volume helps to ensure good aeration. As a consequence of using only a shallow layer of solution, the deep and heavy beds which characterized so many of the earlier hydroponic systems (e. g., sand or gravel culture) are no longer required, being replaced by lightweight polythene sheeting. This not only reduces installation and maintenance costs but also gives far greater freedom to change the layout when required. The concept of NFT was developed by (**Cooper, 1975, 1979)** and is described in a growers bulletin **(Winsor et al., 1979, 1985)** and elsewhere **(Spensley et al., 1978; Winsor, 1980, 1981; Adams, 1981; Wilox, 1982; Graves, 1983).**

Burrage (1992) mention that NFT is one form of soilless production using only recirculating nutrient solution for the production of crop. The provision of adequate nutrients and water to growing plants in the soil or substrate requires precision and monitoring and is often inadequate for the rapidly changing demand, particularly in arid climates. The development of the NFT of culture system removes the necessity for the determination of water requirement and provides the opportunity of more precise control over plant nutrient. As a result it has had considerable attraction to commercial growers.

NFT is a closed system and the solution must contain all the nutrients necessary for plant growth. Unlike the soil, where root system must grow towards the supply of nutrients and water, in NFT water is brought to the root surface. The remaining culture practices, spraying training etc., are similar to plants growing in the soil. The roots in NFT provide little anchorage so protection from wind and additional support may be required.

2.1.1.4. Components of an NFT system:-

In a nutrient film system, a than film of nutrient solution flows through the plastic lined channels which contain the plant roots. The walls of the channels are flexible to permit them being drawn together around the base of each plant to exclude light and prevent evaporation. Nutrient solution is pumped to the higher end of each channel and a pump. The solution is monitored for replenishment of salts and water before it is recycled. Capillary material in the channel prevents young plants from drying out, and the roots son grows into a tangled mat **(Jensen, 1989).**

Burrage (1992) mentioned that the basic features are a series of parallel troughs in which the crop is grown, a catchment tank containing the nutrient solution, circulation pump a flow pipe delivering the nutrient solution to the upper part of the gullies and a return pipe collecting the solution for return to the catchment tank.

An NFT growing system consists of a series of narrow channels through which nutrient solution is recirculated from a supply tank. A plumbing system of plastic tubing and a submersible pump in the tank are basic components. The channels are generally constructed of opaque plastic film or plastic pipe, asphalt coated wood or fiberglass also has been used. The basic characteristics of all NFT systems are the shallow depth of solution that is maintained in the channels **(Davis, 1993).**

2.1.1.5. Design of NFT system:-

Spensley et al. (1978) have shown that increasing the slope of channels from 1/100 to 1/50 had no significant influence on yield.

Resh (1981a) recommended that maximum volume the tank must be 30 to 40% greater that maximum volume required for daily irrigation of each tunnel.

Dudly (1983) recommended that nutrient tank must be painted in the entire surface with a bitumen emulsion and twenty-fours later days or when tank dry, apply a second coat using a bitumen solution.

Jeffreys (1985) said that the following points will usually ensure satisfactory operation of the system

a) Return gullies must slope towards the tank with a minimum fall of 1in 80 (1.25%).

b) Provision must be made for adequate return water bleed-off to prevent salt build upon the pads.

c) Flushable filters must be fitted in the delivery pipe in the vicinity of the pump outlet.

d) Provision must be for easy cleaning of the system without removing the pads.

e) Minimum water flow on to the pads 0.1 l/s per meter. Recommended 0.15 l/s.

f) Minimum pad area required should be calculated using the highest average summer solar radiation values and he recommended increasing the calculated area by about 25%.

Lim (1986) found overcame this difficulty by using wooden troughs that insulate the solution from the surrounding environment.

Fahim (1989) developed a simple system which is appropriate to save expensive construction with simplified solution-circulation. They reported that for lettuce and squash zucchini, the appropriate gully width was lo cm, bottom slope 2%, and rate of flow 1-1.5 l/h/2m run for the lettuce and squash zucchini. The consumptive use of water ranged between 7 and 9 l/lettuce plant in 90 days, and 5.5-7 l/squash plant in 70 days. The plant water-use efficiency amounted to 6 g/l for lettuce and 1.5 g/l squash right prior to fruiting. It was remarkable that the saving in water use amounted to 90% for lettuce compared with intensive irrigation. The paper also contained other results about roots growth, volume, dry mass, and plant spacing.

Awady et al. (1992) studied that the different channel slopes, flow rates and biomass, as a source of nutrient in addition to Hoagland and Arnon-solution, on cucumber culture to develop structures and materials appropriate for the functioning of the NFT. They found that the maximum “water-use efficiency: WUE” was obtained with channel slope of 4% and high flow rate of both solutions. The ratios of N/water and K/water increased with time until they leveled off at the productive stage. Generally, number of plants and maximum Fruit yields of cucumber per unit area were 8 and 2.89 times as much as conventional system, respectively WUE was maximum (0.5%) at a channel slope of 2% and a low flow rate of biomass-solution.

In a closed system, the life of the nutrient solution is 2-3 weeks, depending upon the season and stage of plant growth. In some cause it is possible to add partial formulations between changes. In addition to changes in nutrient composition, the pH also changes. Also, the solution volume must be kept relatively constant in order to source adequate plant growth **(Resh, 1981).**

The maximum length of the channels should not be greeter that 15-20m. In a level greenhouse, longer runs could restrict the height available for plant growth, since the slope of the channel usually has a drop of 1 in 50 to 1 in 75. Longer runs and or channels, with less slope, may accentuate problems of poor solution aeration **(Jensen, 1989).**

2.1.1.6. Environmental Factors.

a- Solution temperature:-

Cooper (1979) mentioned that one of the major advantages of NFT cropping is that it provides the facility in large-scale crop production to control the root environment more precisely than has been possible in the past conventional agriculture. One of the factors of the root environmental over which some control can be achieved in NFT cropping is root-zone temperature. In conventional agriculture the soil temperature prevailing has to be accepted, it is impractical to do very much to influence it. In NFT cropping the root-zone temperature can be controlled because the temperature of the recirculating water can be controlled. The cost of control will be the main determinant of the degree and the precision of control.

Burrage and Varley (1980) grew lettuce crops (Cv. Dandie) in solution constantly heated to four different levels-nominally 10˚C, 15˚C, 20˚C and 25˚C. They recommended that:

I- An optimum temperature for NFT lettuce production without air heating would be 15 to 20°C.

II- The NFT solution conductivity for lettuce production only would be 25 to 35 CF.

III- PH levels would be 6.0 to 6.5.

Hewitt (1981) explained that the heat input requirement for the NFT solution depends on several factors.

a- Quality and solution in the system.

b- Quantity and temperature of replenishment water over a given period (1hour).

c- Flow rate of recirculation solution.

d- Length and slope of individual NFT beds.

e- Air temperature in the glasshouse.

There are currently two acceptable methods of nutrient solution heating,

- By means of submerged electric heating coil.
- By means of an in-line heat exchanger.

Resh (1981) explained that in greenhouse culture the temperature of the nutrient solution in contact with the roots should not fall below the high air temperature of the house. Immersion heaters can be placed in the sump to heat the nutrient solution, but care must be taken not to use heating elements such as lead which may react electrolytically with the nutrient solution to release toxic amounts of ions into the solution. Heat lamps could be used instead of immersion heaters.

Jensen (1985) found that root temperatures of lettuce must not exceed much more than 20ºC, especially when air temperatures are 32-35ºC or above, due to the problem of bolting (formation of the seed stalk). It was found that cooling the nutrient solution dramatically reduced bolting as well as lessening the incidence of the fungus pythium aphanidermatum, which also affects the establishment and yield of hydroponic tomato and cucumber crops.

Moss (1985) concluded that root zone warming (RZW) is most suitable for soilless cultivation where either the recycled nutrient solution is warmed, as far NFT, or where warm water pipes are used to heat rock-wool or other media. Benefit from RZW varied with the crop. Roses were very responsive, and cv. Mercedes (on rosa multiflora root stock) gave a 100% higher yield in the second winter with RZW to 25°C and no air warming, than with a night air temperature 18ºC;there was also a considerable saving in energy.

Graves (1986) recommended that solution temperature should be maintained at 15-18°C before picking starts to ensure high fruit quality and raised to 25°C subsequently to increase root and shoot growth and fruit yield. The greatest benefit from intermittent solution circulation was a marked improvement in the quality of fruit picked early in the season, Fifteen minutes of circulation for every 0.6MJ of total radiation received within the glasshouse in winter gave the best results.

Morgan and Moustafa (1986) showed that chrysanthemum which was grown in NFT with root zone warming 21 to 27°C could advance the harvest by up to 12 days.

Hicklenton and Wolynetz (1987) found the following results for tomato plants grown in recirculating solution culture in growth chambers under day temperature (TD) of 12, 15, 19.5 or 22.5°C, night temperatures (TN) of 5 or 14ºC, and root zone temperatures (TR) of 20, 23 or 26°C, (1) There were no significant interaction between (TD) and (TN) effects. (2) An increase in (TD) from 12 to19.5°C increased fresh and dry leaf at final harvest, but increasing (TN) from 5 to 14°C had little effect. (3) Specific lead area increased with increasing (TN). (4) The effect of (TR) on plant size was minor. (5) Lead area increased with (TR) up to 26°C. Table (2.1) summarizes the minimum, maximum and optimum temperature for vegetables production in hydroponics.

Table (2.1). Temperature minimum, maximum and optimum for vegetables production in hydroponics.

Crop	Minimum	maximum	Optimum
Lettuce	2	24	21
Tomato	10	32	24
Cucumber	15	32	24
Cabbage	4	38	29
Pepper	15	35	27
Spinach	Zero	29	21
Cauliflower	4.5	35	27
Eggplant	15	35	29
Melon	18	35	29
Watermelon	18	35	29
Cantaloupe	15	32	24
Zucchini	15	32	24

(Lorenz and Maynard, 1980; Aboulrous and Sheriff, 1995).

b- pH solution and its measurement:-

Cooper (1979) mentioned that the PH of the nutrient solution for most NFT crops should not be allowed to rise above 6.5 or to fall below 6.0. If the PH of the solution is being adjusted manually it should be measured daily, If the local water supply is sufficiently acid the PH will fall, if it is not sufficiently acid the PH will rise. If the PH rises acid should be added to the solution to reduce the PH to 6.0 whenever the PH value has risen to 6.5. If the PH falls a sufficient quantity of a base should be added to the solution to raise the PH to 6.5 whenever the PH value has fallen to 6.0.

He also recommended that the best method for NFT cropping is to use a portable PH meter. This is a small, battery-operated instrument with a propel which is place in a sample of the nutrient solution. When electric current is allowed to flow from the battery a needle on the instrument moves a long a PH scale. The PH value of the liquid under test is indicated by the value on the scale at which the needle comes to rest.

Sonneveld (1980) recommended that the pH of the solution within the rockwool slabs should preferably be maintained at 5.0- 6.0, or 5.0-6.5 in the rockwool during propagation. Table (2.2) summarizes the pH appropriate for vegetables production in hydroponics.

Table (2.2). pH appropriate for vegetables production in hydroponics.

Crop	pH	Reference
Lettuce	6-6.5 6-7.6	(FAO, 1991) and (Barraged and Varly, 1980) Hassn, 1989.
Tomato	6-6.5 5.5-6.8	FAO, 1991 Hassn, 1989
Cucumber	5.5-6.8	Hassn, 1989
Strawberry	5-6	FAO, 1991
Zucchini (Squash)	5.5-6.8	Hassn, 1989
Pepper	5.5-6.8	Hassn, 1989
Cabbage	6-7.6	Hassn, 1989

c- Solution EC and its measurement:-

Jensen (1971) recommended that under the experimental condition, the electrical conductivity "EC" of the nutrient solution for tomato crop should not be allowed to drop below 2.5 or rise over 3.5 ds/m.

Cooper (1979) mentioned that CF of the nutrient solution for most NFT crops should not be allowed to fall below 20 (2 millimhos or 2000 micromhos). If the CF of the solution is being adjusted manually it should be measured daily. As the crop removes the nutrients from the recirculating solution its electrical conductivity will decrease. When the CF falls to 20 sufficient nutrients should be added to the solution to increase the CF to a value approaching 30. These nutrients can be added to the recirculating solution as solid substances or as a concentrated stock solution.

Wittwere and Honme (1979) agree with **(Jensen, 1971)** recommendation about EC, and they added that when the PH of the recirculating solution rise to 7.5 phosphoric acid or nitric acid should be added to keep the PH within the range of 6.0 - 7.5.

Sonneveld (1980) recommended that the solution within rockwool slabs during cropping should have conductivities of 2.0 - 2.5 ms/cm for cucumbers and 2.5 - 3.0 ms/cm for tomatoes.

Graves and Hurd (1983) found that the yield of cucumber plant increase to 60kg/m^2 during 30 week when EC is about 2.5 - 4mmhos/cm. Table (2.3) summarizes the EC appropriate for vegetables production in hydroponics.

Table (2.3). EC appropriate for vegetables production in hydroponics.

Crop	EC	Reference
Lettuce	2 ds/m 1.3 ds/m	FAO, 1991 Hassn, 1989
Tomato	2.5 ds/m	Hassn, 1989 and FAO, 1991
Cucumber	1.2-3.8 ds/m 2.5-4 ds/m 2.5 ds/m	Sonneveld, 1981 Graves and Hurd, 1983 Hassn, 1989
Strawberry	2 ds/m	FAO, 1991
Zucchini	4 ds/m	Hassn, 1989
Pepper	1.5 ds/m	Hassn, 1989
Cabbage	1.8 ds/m	Hassn, 1989

d- Aeration:

As in all hydroponic systems it is important to maintain the highest possible level of oxygen in the nutrient solution at all times. Design factors which help to achieve this result include adequate flow rates, wide gullies and shallow solution. The solution flowing in the gullies does indeed take up oxygen from the air, as demonstrated by (**Gislerod and Kempton, 1983).** Thus a solution depleted of oxygen (3mg O_2 /l) by bubbling nitrogen through it contained 4.2 mg/l and 5.5 mg/l at distances of 1.5 and 5 m along a gully not containing plants. The reverse gradient was, found when plants area present; oxygen consumption in the root zone then exceeded oxygen uptake from the air.

Zeroni et al. (1983) concluded that 65% of O_2 saturation was the lowest desirable level for both vegetative and reproductive growth of tomatoes.

Depletion of oxygen levels in the solutions used cucumbers doubtless reflects the large root system produced by this crop. Micro-organisms in the gullies will also utilize oxygen, and anything which increases the microbiological population is thus undesirable. Root damage, however caused, would be expected to increase biological oxygen demand by favoring the development of saphrophytic organisms. This factor was simulated in the studies of **(Gislerod and Kempton, 1983)** by daily additions of glucose as a readily metabolized substrate; values as low as 1 mg O_2/l resulted, accompanied by wilting of the plants on sunny days.

The oxygen content of nutrient solutions circulating around plant roots declines to a minimum during the brightest part of the day. The oxygen deficit is highly correlated both with solution temperature and with the amount of acid required to maintain the pH of the solution **(Gislerod and Adams, 1983).**

Resh (1983) reported that best results can be achieved in a system in which the nutrient solution is pumped into the beds and allowed to flow past the plant roots continuously. In this way freshly aerated solution will be in content contact with the plant roots.

A cheaper alternative is to introduce oxygen into the solution. This may be achieved in one of two ways. First, forced aeration (by using air pump) is used to bubble air into the nutrient solution through a perforator pipe placed at the bottom of the bed or container. Second, the nutrient solution is circulated with or without a pump through the beds and black to reservoir **(Dixie, 1985 and Hegazi, 1986).**

2.1.2. Aquaculture:

Aquaculture is the art of cultivating the natural products of water. By “aquacultural systems” we mean the commercial production systems of aquatic animals either in controlled or uncontrolled environment **(Bala and Satter, 1989).** Aquaculture is the science and technology of producing aquatic plants and animals **(Lawson, 1995)**.

Aquatic production systems are typically classified according to type (static system “open system” flow-through system “recycle system”. Raceway “reuse system” and Cage system). Biomass density (extensive, semi – intensive, intensive and super intensive), and feeding practices (natural and artificial feeding), **(krom et al., 1989).**

Many aquaculture systems have been developed **(Chen et al., 1989; Menasveta et al., 1989, 1991, 2001; Millamena et al., 1991; Heinen et al., 1996; Twarowska wt al., 1997; Davis and Arnold, 1998; Greiner and Timmons, 1998; Singh et al., 1999; Losordo et al., 2000; Ridha and Cruz, 2001).**

2.1.2.1. Water Recycle System Components:-

Water recycle system is consists of four main components:

I- Fish Tank:-

Tanks of nearly any shape are available and are used for various functions in fish culture. However most tanks can be classified as circular, rectangular, or oval with a dividing wall. Circular tanks are often used, with the water inlet providing tangential velocity component. This component causes a rotary tank circulation. Discharge typically is through the tank center by means of a standpipe or bottom drain, **(Wheaton 1993; Lawson, 1995; Soderberg, 1995).**

II- Waste solids tanks:-

The decomposition of solid fish waste and uneaten or indigestible feed can use a significant amount of oxygen and produce large quantities of ammonia-nitrogen. There are three categories of waste solids settleable, suspended, and fine or dissolved solids.

a- Settleable solids:-

Settleable solids are generally the easiest to deal with and should be removed from the culture tank water as rapidly as possible. This is easiest when bottom drains are properly placed. In tanks with circular flow patterns (round, octagonal, hexagonal, square with rounded corners) and minimal agitation, settleable solids can be removed as they accumulate in the bottom center of the tank, in a separate, small flow-stream of water, or together with the entire flow leaving the tank. Center drains with two outlets are often used for the small flow-stream process **(Losordo, 1997).**

A drain is a particle trap, in this design, settleable solids flow under a plate, spaced just slightly off the bottom of the tank, in a flow of water that amounts to only 5 percent of total flow leaving the center of the tank. The larger flow (95 percent the total) exits the tank through a large discharge strainer mounted at the top of the particle trap. Outside of the tank, the settleable solids flow- stream from the article trap enters a sludge collector. The waste particles settle and are retained in the sludge collector and the clarified water exits the sludge collector at the top and flows by gravity for further treatment. The sludge in the collector, which has an average dry weight solids content of 6 percent, is drained from the bottom of the collector **(Hobbs et al., 1997).**

b- Suspended Solids.

From an engineering viewpoint the difference between suspended solids and settleable solids is a practical one. Suspended solids well not easily settle out of the water column in the fish culture tank. Suspended solids are not always dealt with adequately in recirculating systems. Most current technologies for removing suspended solids generally involve some from of mechanical filtration. Two types of mechanical filtration are screen filtration and expandable granular media filtration **(Losordo et al., 1999).**

c- Fine and Dissolved Solids.

Many of the fine suspended solids and dissolved organic solids that build up with intensive recirculating systems cannot be removed with traditional mechanisms. A process called foam fractionation (also referred to as air-stripping or protein skimming) is often employed to remove and control the build- up of these solids. Foam fractionation is a general term for a process in which air introduced into the bottom of a closed column of water creates foam at the surface of the column. Foam fractionation removes dissolved organic compounds (DOC) from the water column by physically adsorbing DOC on the rising bubbles. Fine particulate solids are trapped within the foam at the top of the column, which can be collected and removed. The main factors affected by the operational design of the foam fractionators are bubble size and contact time between the air bubbles and the DOC. A counter-current design (bubbles rising against a downward flow of water) improves efficiency by lengthening the contact time between the water and the air bubbles **(Losordo, 1997).**

III- Biological Filter:-

There are many descriptions of water recirculation systems using biological filters for intensive cultivation of various species, but few authors discuss the basis for their choice of biological filter evaluation parameters **(Rogers and klemetson, 1985).**

Liao and Mayo (1974) and speece (1973) have proposed two important biological filters design methods. These methods are based primarily on nitrogen production of the species to be cultured. Both design method, are based on limited data, were developed for cold fresh water species, and are limited in application **(Wheaton, 1993)**

Biological filtration is defined as the bacteriological conversion of organic nitrogenous compound into nitrate. The primary purpose of a biological filter is conversion of ammonia to nitrite, and nitrite to nitrate. This conversion is of great importance in culture of aquatic organisms because ammonia is highly toxic metabolic waste discharge directly by many cultured organisms and generated as a by product by many bacteria. Nitrite is some what less toxic than ammonia. Nitrate is considered relatively nontoxic to most aquatic organisms **(Wheaton, 1993).**

Biological filtration in the broadest sense includes any filtration technique that utilizes biological (living) organisms to remove impurities from the water. Although biological filtration can include living plant filters, nitrification identification, extended aeration systems and a host of other types of filters of unit processes **(Wheaton et al., 1991).**

Biological filtration is often employed as a water purification method in high density, semi-closed or closed aquaculture facilitates the growth of nitrifying bacteria, which oxidize ammonia via nitrite to nitrate **(Rijna and Rivera, 1990).**

-Biological filter Types:-

Wheaton (1993) and Lawson (1995) reported that, there are many types of biological filters. Those most often used in aquaculture include submerged, trickling, biodrums, and biodisks in recent, however, there types like rotating biological contactors and Fluidized beds have been shown to be more efficient at ammonia removal.

IV- Aeration Tank

Aeration is used here to refer to the dissolution of oxygen from the atmosphere into water, the transfer of pure oxygen gas to water is referred to as oxygenation:

a- Aeration:

Air-contact aeration systems transfer all gases present in atmospheric air into water. These systems can only increase dissolved oxygen concentrations to saturation, and the efficiency of oxygen transfer declines as the dissolve oxygen concentration in water increase **(Boyd, 1982).** Air-contact aerators actually transfer oxygen from water to air if the water is supersaturated with oxygen – they become de gassers. Gravity aerators rely on available head require no external power; water simply falls over a weir, flows through a series of expanded metal screens, or splashes onto a surface. Gravity aerators often are used in raceways and where well water is discharged into ponds or fish – holding tanks **(Boyd, et al., 1978).**

Mechanical surface aerators splash water into the air to accelerate the rate of oxygen absorption **(Ray, 1981).** Subsurface diffused –air aerators consist of an air blower or air compressor that forces air into an air-delivery system that is suspended in the pond bottom **(Ray 1981).**

Colt and Orwicz (1991) and Boyed and watten (1989) reported that the aeration devices can be classified as:-

-Surface aerator

-Subsurface aerator and

- Gravity aerator.

b-Oxygenation:

Pure oxygen is used in recirculating systems when the intensity of production causes the rate of oxygen consumption to exceed the maximum feasible rate of oxygen transfer through aeration. Sources of oxygen gas include compressed oxygen cylinders, liquid oxygen and on-site oxygen generators. In most applications, the choice is between bulk liquid oxygen and an oxygen generator. The selection of the oxygen source will be a function of the cost of bulk liquid oxygen in your area (usually dependent on your distance from the oxygen production plant) and the reliability of the electrical service needed for generating oxygen on-site **(Boyd and watten, 1989).**

Adding gaseous oxygen directly into the culture tank through diffusers is not the most efficient way to add pure oxygen gas to water. At best, the efficiency of such system is less than 40 percent. A number of specialized components have been developed for use in aquaculture application **(Boyd and Watten, 1989)**. The more commonly used components follows:

- Down– flow bubble contactor.
- U-tube diffusers.
- Low head oxygenation
- Pressurized packed columns.

2-1-2-2-Environmental factors:-

Environmental factors are critical in aquaculture, because survival, reproduction, and growth of aquaculture species depend upon a satisfactory environment. There are many environmental factors in effluence pond aquaculture, but fortunately, only a few normally has a decisive role. Temperature and salinity are important in that they limit the kinds of organisms that can be cultured at a particular place. Nutrient concentration, total alkalinity, and total hardness are important factors regulating plant productivity, which, in turn, influences the availability of food organisms for aquatic animals. Turbidity regulates light penetration in pond water to affect photosynthesis and food webs; turbidity also has direct effects on fish and invertebrates. Other variables influential in aquaculture ponds are pH, dissolved oxygen, Carbon dioxide, ammonia, nitrite, and hydrogen sulfide. In a few cases, toxic metals and pesticides may enter aquaculture ponds as pollutants. Toxic pollutants normally are of loss concern in aquaculture than toxic substances, which result from processes with in the culture system **(Boyd, 1990).**

Soderberg (1995) cited that water quality is widely acknowledged to be one of the most important rearing conditions that con be managed to reduce disease exposure and stress in intensive fish culture. However, the physiological tolerance of fish to water quality alterations is affected by a number of environmental and biological variables and it is not a simple matter to identify specific chemical constituents, temperature, or dissolved gas concentration that will provide optimum rearing conditions under all circumstances. First, the effects of water quality conditions on fish health very considerably with species, size and age. Second, the water quality conditions themselves (particularly pH, dissolved oxygen, and temperature) can greatly alter the biological effect of dissolved substances.

- Metabolic Products

I-Ammonia:

Ammonia is the main product of protein metabolism in fish and is mainly excreted via the gills **(Smith, 1929; Wood, 1958). Waarde (1983)** reported ammonia to be the major component of nitrogen excretion, and its production rate directly related to protein oxidation. The major source of ammonia in pond water is the direct excretion of ammonia by fish **(Tucker and Boyd, 1985).** Ammonia is the principle nitrogenous by – product of fish in its unionized from. The origin of metabolic ammonia is the deamination of amino acids utilized as energy. A metabolic nitrogen budget allows for the estimation of the contribution of dietary protein to the accumulation of ammonia in the water **(soderberg, 1995).**

- **Ammonia Toxicity:**

Aqueous ammonia occurs in two molecular forms and the equilibrium between them is determined by pH, and to a lesser extent, temperature:

$$NH_3 \longleftrightarrow NH^+_4$$

and

$$NH_3 - N + NH^+_4 - N = TAN$$

The unionized form NH_3 is a gas and can freely pass the gill membrane the rate and direction of passage depends upon the NH_3 concentration gradient between the fish's blood and the adjacent water. Unionized ammonia NH_3 is toxic to fish while ionized ammonia NH_4 is relatively nontoxic. Analytical procedure dissolved oxygen not differentiates between the two forms of ammonia in solution, and only one is of consequence to the fish culturist. Thus, it is important to be readily able to determine the fraction of NH_3 in solution at any temperature and pH **(soderberg, 1995).**

$$F = \frac{1}{10^{pKa-pH} + 1}$$

The unionized fraction, F, is the decimal fraction of NH_3 in an ammonia solution.

Thus, NH_3 – N = TAN x f

Emerson et al., (1975) present the following formula to calculate the acid dissociation constant, expressed as the negative log, for ammonia, based on the values of **Bates and Pinching (1949)**:

$$\boldsymbol{pKa = 0.09018 + \frac{2729.92}{T}}$$

Where: Pka = negative log of the acid dissociation constant for ammonia T = temperature, ^{o}K.

II-Nitrite:

Nitrite (No_2 – N) is the ionized from of nitrous acid (HNo_2), and it can be as lethal as NH_3- N. nitrite levels in fish ponds typically ranges from 0.5 to 5 mg/L, probably due the reduction of nitrate in anaerobic mud or water **(Boyd, 1982).**

The toxicity of (No_2 – N) is due principally to its effects on oxygen transport and tissue damage. When nitrite is absorbed by fish the hem iron in blood hemoglobin is oxidized from the ferrous to the ferric state. The resulting product is called methemoglobin (blood brown) or ferri hemoglobin and is not capable of combining with oxygen **(Tuker and Boyd, 1985).**

Representative acute toxicity values for nitrite for some species of fish are ranged from 0.2-190 mg/L **(Russo and Thurston, 1991).**

In flow- through systems, ammonia is the principle toxic metabolite water generally does not have along enough residence time in flow – through system for nitrite to become a problem. However, nitrite often is a serious problem in recirculating systems where the water is continually reused. In recirculating systems, nitrite is controlled with biological filters, but can accumulate to toxic levels if the biological filters are not functioning properly or if the system temperature is below the functional range for Nitrobacter bacteria **(Lawson, 1995).**

III-Nitrate:

Nitrates are the least toxic of the inorganic nitrogen compounds **(Wickins, 1976; colt and tchobanoglous, 1976).**

Nitrate building occurs most in the fall in pond systems when water temperatures are cooler **(Lawson, 1995).** Representative acute toxicity values for nitrate for some species of fish are ranged from 180-1400 mg/L **(Russo and Thurston, 1991).**

A drawback of ammonia removal by means of nitrification if the subsequent increase of nitrate in the culture system. Nitrate concentrations of up to 800 mg/L No_3 – N have been recorded in semi – closed aquaculture facilities where aerobic biological filtration was employed **(Rijn and Rivera, 1990).** High nitrate concentration ought to be prevented for mainly two reasons. Firstly, nitrate at high concentrations have a toxic effect on several fish species **(Muir, 1982),** and secondly the discharge of nitrate rich effluent water is prohibited in many countries due to environmental and public health considerations **(Rijn and Rivera, 1990).** The maximum levels of nitrate allowed in the effluent water differ from country and are as low as 11.6 mg / L No_3-N in Europe according to the European community directive.

Nitrate is relatively harmless to fish and other cultured aquatic organisms and for this reason relative little attention has been paid to nitrate removal in intensive fish culture systems **(Russo and Thnston, 1991).**

(Otto and Rosenthal, 1979) reported that, the very high nitrate concentrations encountered in the intensive aquaculture systems (Sometimes more than 1 g/L) should be avoided, mainly for two reasons:

Nitrate accumulation**:** Nitrate is either an intermediate or an end product of nitrate respiration, a process conducted by a wide array of assimilatory and dissimulator nitrate reducing microorganisms **(Payne, 1973).** Although it is assumed that nitrate respiration is a strict anoxic process, differences exit as to the inhibitory effect of oxygen on the different enzymes involved in nitrate respiration form studies concerned with oxygen inhibition on nitrogen oxide reducing enzymes it is apparent that among these enzymes, nitrate reeducates (reducing nitrate to nitrite) is least sensitive to oxygen **(Hochstein et al., 1984).** Therefore intensive fish culture systems in which nitrate is allowed to accumulate will experience high background levels of nitrite due to the fact that oxygen – poor microsites (e.g. organic matter at the bottom of the culture system or within the aerobic, nitrifying filters) will harbor bacteria capable of reducing nitrate to nitrite only.

Environmental considerations: High nitrate levels in surface and ground waters might give rise to environment problems such as eutrophication and contamination of drinking water. Nitrate – rich drinking water has been coupled to methamoglobinemia in infants and gastric cancer **(Taylor, 1975; Jensen, 1982).** It is anticipated that the growing awareness of nitrate pollution will lead to more stringent environmental restriction in regard to discharge of nitrate – rich water.

3- MATERIALS AND METHODS

The main objective of this research is to study to which extent the content of nutrients in water farming is sufficient for growing plants. The practical part of this work was carried out at El-Nenaiea farm, Ashmon, El-Minufiya governorate. During 2006 season. Table (3.1) shows the input parameters of the experiment.

Table (3.1). The experimental inputs of the experiment:

Date of start	16/ 3/ 2006
Date of end	5/ 5/ 2006
Experimental duration (day)	50
Initial average weight of individual fish (g)	60
finial average weight of individual fish (g)	118
Initial density (kg/m³)	18
finial density (kg/m³)	35

3.1. Materials:

3.1.1. System Description:

Figure (3.1) illustrates the design of the experimental. It consists of the following components.

3.1.1.1. Fish Tanks:

The system consists of three circular concrete tanks were used for fish culture. Dimensions of tanks are (5m diameter x 1.25m height), (8m diameter x 1.25m height), and (10m diameter x 1.25m height). The water volumes used in tanks were 25, 50, and 100 m³ respectively. Each tank was provide to a particle trap in the center for water drain waste solids, settleable solids flow under a plate, in a flow of water that amounts to only 5 percent of the total flow leaving the center of the tank. The larger flow (95 percent of the total) exits the tank through a larger discharge strainer mounted at the top of the particle trap.

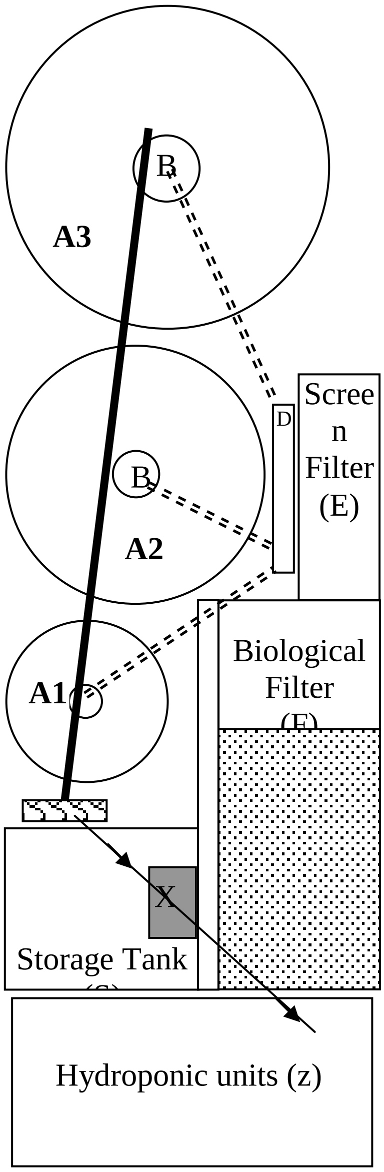

Figure (3.1). Sketch of the water recycle system. Fish tank, A; particle trap, B; channel collector, D; screen filter, E; biological filter, F; storage tank, S; pumps, G; heat exchanger, X; Hydroponic units, Z.

Outside of the tank, the settleable solids flow-stream from the particle trap enters a sludge collector. The waste particles settle and are retained in the sludge collector and the clarified water exits the sludge collector at the top and flows by gravity for further treatment.

3.1.1.2. Screen Filter:

Rotating drum was used in this system, water enters the open end of a drum and passes through a screen attached to the circumference of the drum. The filter dimensions were 1.3m diameter and 2m length. The fine mesh silk 100 micron was used a media of screening.

3.1.1.3. Biological Filter:

Rotating Biological Contactor (RBC) was used, approximately 40 percent of the substrate is submerged in the recycle water. The filter dimensions were 1.5m diameter and 2m length. Polyethylene tubes were used a media to carry bacteria. The RBC described by **Ali et al. (2006)** in press.

3.1.1.4. Oxygen Generator:

Pure oxygen used in this system source of oxygen gas was oxygen generator table (3.2) and plate (3.1).

3.1.1.5. Oxygen Mixer:

Adding pure oxygen gas to water by oxygen mixer table (3.3) and figure (3.2). The water and oxygen enter the top of the oxygen mixer, as the water and oxygen move downward.

Table (3.2). The specifications of oxygen generator.

Origin of manufacture	Egypt
Model	M.R.D
Discharge	1.8 m3/hr
Pressure	4 bar
Purity	94%
Power	140 W, 220 V, 50Hz
Dimensions	1 (L) x 0.7 (W) x 2.3 (H) m

Plate (3.1). Oxygen generator.

Table (3.3). Specifications of oxygen mixer.

Origin of manufacture	Egypt
Type	Oxygen saturators
Flange in diameter	6 inch.
Flange out diameter	6 inch.
Diameter input of oxygen	0.5 inch.
Efficiency	85%
High	3.5 m
Dimension	Part A 80 cm length x 6 inch diameter Part B 80 cm length x 10 inch diameter Part C 90 cm length x 14 inch diameter Part D cone shape, the minimum base 45 cm, the maximum base 125 cm and the length 100cm

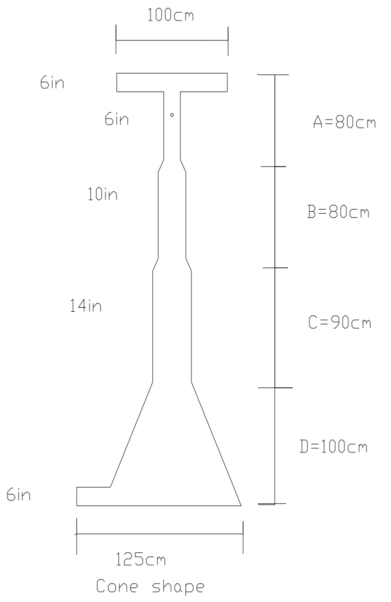

Figure (3.2). Oxygen mixer.

3.1.1.6. Hydroponic Units:

The hydroponic units in this study consisted of:

- Two sources of nutrient solution were used:

(1) Stock nutrient solution

(2) Water discharged from the fish farm.

- Three lengths of gully 2, 3 and 4 m

- Three water flow rates 1, 1.5 and 2 lit min^{-1}

Intermittent flow (1 minute 'on' and 4 minute 'off') as described by **Benoit and Ceustermans (1989)**.

Figure (3.3) shows the design of hydroponic units. The gullies were 50 cm wide, slope 2% and stand 1m high above the ground with row spacing of 20cm.

The gullies were made from iron frame, covered by plastic sheet and foam boards were used to support plants.

The solution was pumped from the tank to the upper ends of the gullies. Small tubes were used supply each gully by nutrient solution or water discharged of the fish farm. Nutrient solution is circulated in closed system. The tank of the nutrient solution system 200 liter capacity was used for collecting of drained solution by gravity from the ends of the gullies. The amount of chemicals used in the second system as described by **Hoagland and Arnon (1950).** The chemical composition of Hoagland and Arnon solution are shown in table (3.4). Also a complete replacement for the nutrient solution was done every ten days **(Fahim, 1989).**

Table (3.4). Chemical composition of Hoagland and Arnon solution.

Chemical	**Formula**	**Mass mgl^{-1}**
Potassium dihydrogen phosphate	KH_2PO_4	136.0
Potassium nitrate	KNO_3	505.0
Calcium nitrate	$Ca(NO_3)_2. 4H_2O$	1180.0
Magnesium sulfate	$MgSO_4. 7H_2O$	492.0
Iron chelates	Fe-EDDHA	40.0
Manganese chloride	$MnCl_2. 4H_2O$	1.81
Zinc sulfate	$ZnSO_4. 7H_2O$	0.22
Copper sulfate	$CuSO_4. 5H_2O$	0.08
Boric acid	H_3BO_3	2.86
Molybdic acid	$H_2MoO_4. H_2O$	0.02

From Hoagland and Arnon (1950). The following ppm concentrations are achieved in this formulation: N=210, P=31, K=234, Ca=200, Mg=48, S=64, Fe=14, Mn=0.5, Zn=0.05, Cu=0.02, B=0.5 and Mo=0.01.

3.1.1.6. Pumps:

Table (3.5) shows the specifications of pump.

Table (3.5). Specifications of pump.

Origin of manufacture	Italy
Type	Calbida
Flow Rate	Maximum 12 m^3/hr
Head	Maximum 48 m
Power	1.5 kw

3.1.2. Instruments:

Ammonia (NH_3) was measured by a speckol 11(table 3.6 and plate 3.2). Nitrite (No_2) and nitrate (No_3) were measured by ISE Meter (table 3.7 and plate 3.3). Phosphorus (P) was measured by a spectrophotometer (table 3.8 and plate 3.4). Potassium (K) was measured by flame photometer (table 3.9 and plate 3.5). The pH was measured by the pH meter (table 3.10 and plate 3.6). The EC was measured by the EC meter (table 3.11 and plate 3.7).

Table (3.6). Specification of Speckoll 11.

Origin of manufacture	UK
Model	11
Wavelength	349-850nm
Bandwidth	5nm
Ranges	0 to 100.0% T. 0 to1.999Abs 0.1 to 1000 Concentration
Resolution	0.1% T. 0.001Abs. 0.1to1.0 Concentration ± 1 nm λ
Wavelength Accuracy	± 2 nm
Photometric Accuracy	±1% or±0.005A whichever is greater
Photometric Noise levels	< 0.001A
Photometric Stability	0.004A/Hr after warm-up
Stray Radiant Energy	< 0.5% at 340nm
Readouts	3 digit LED, %T, Abs, Conc. (20nm) 3 digit LED, λ
Outputs	Analogue (0–IV for 0–1A) Centronics parallel port RS232 serial port
Light Source	Tungsten Halogen
Power	100/115/200/230 Vac ±10% 50/60Hz
Size	340 x 460 x 350mm
Weight	11Kg

Plate (3.2). Speckoll 11.

Table (3.7). Specifications of Ion Selective Electrodes (ISE).

Origin of manufacture	USA
Model	ORION 710A
pH Range	-2 to 19.999
Resolution	0.001/ 0.01/ 0.1
Relative Accuracy	±0.005
Slope	80 to 120%
Auto-Buffer-Recognition	1.68, 4.01, 7.00, 10.01, 12.46
Temperature Range	-5 to 105 ºC
Temperature Resolution	0.1 ºC
Display	Custom LCD
Inputs	1 BNC, 1 pin tip, ATC, Power, RS232
Power Requirements	AC line, 110 V, 220 V or 240 V
Dimensions	

Plate (3.3). Ion Selective Electrodes (ISE).

Table (3.8). Specification of Spectrophotometer.

Origin of manufacture	UK
Model	6100
Wavelength	320-920nm
Bandwidth	5nm
Ranges	0 to 100.0% T. 0 to 1.999Abs 0.1 to 1000 Concentration
Resolution	0.1% T. 0.001Abs. 0.1to1.0 Concentration ± 1 nm λ
Wavelength Accuracy	± 2 nm
Photometric Accuracy	± 1% or ± 0.005A whichever is greater
Photometric Noise levels	< 0.001A
Photometric Stability	0.004A/Hr after warm-up
Stray Radiant Energy	< 0.6% at 340nm
Readouts	3 digit LED, %T, Abs, Conc. (20nm) 3 digit LED, λ
Outputs	Analogue (0–IV for 0–1A) Centronics parallel port RS232 serial port
Light Source	Tungsten Halogen
Power	100/115/200/230 Vac ±10% 50/60Hz
Size	520 x 330 x 180mm
Weight	12Kg

Plate (3.4). Spectrophotometer.

Table (3.9). Specifications of flame photometer.

Origin of manufacture	USA
Model	Jenway PFP7
Ranges	120-160 mmol/l Na - 0-10 mmol/l K
Limits of detection	Na/K=0.2 ppm. Li=0.25 ppm. Ca=15 ppm. Ba=30 ppm.
Reproducibility	1% coefficient of variation
Linearity	Better than 2% when concentration of 3 ppm Na/K
Specificity	< 0.5%
Outlet	Nominal 1 V for a reading of 100
Power	90 – 125 V or 190 – 250 V at 50/60 Hz
Size	420 x 360 x 300 mm
Weight	8 Kg

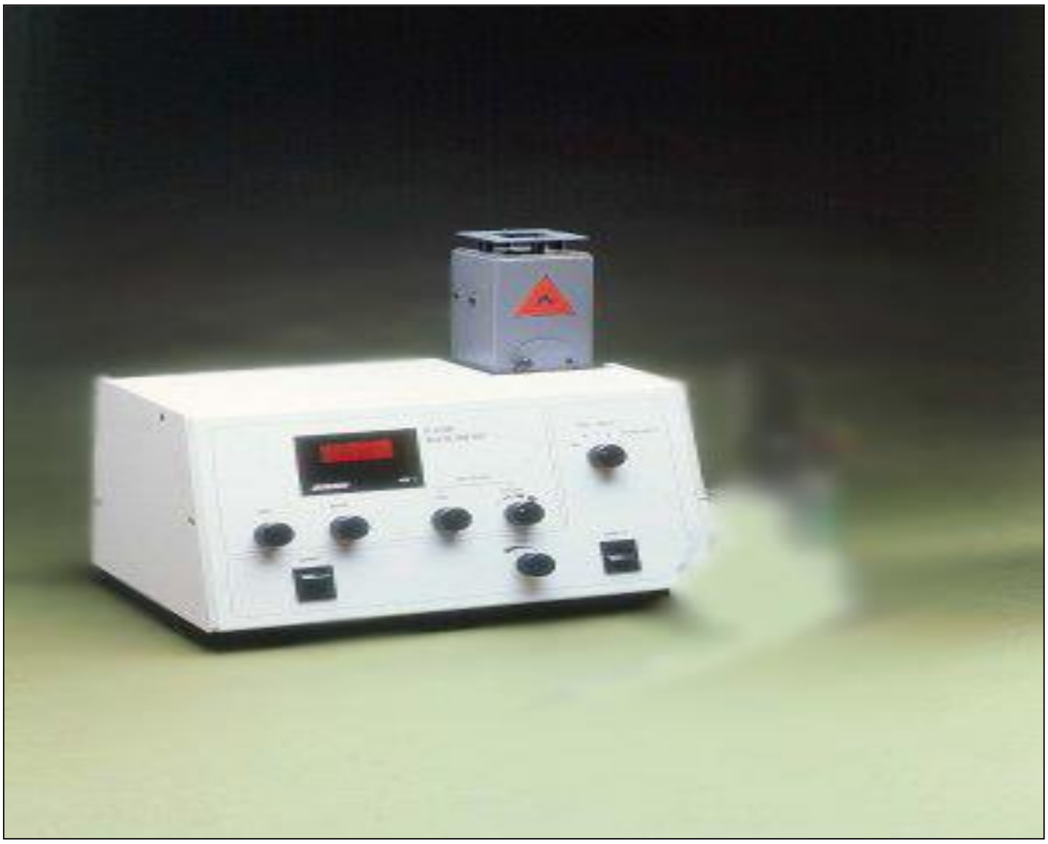

Plate (3.5). Flame Photometer.

Table (3.10). Specifications of pH Meter.

Origin of manufacture	USA
Model	ORION 230A
pH Range	-2 to 19.999
Resolution	0.001/ 0.01/ 0.1
Relative Accuracy	±0.005
Slope	80 to 120%
Auto-Buffer-Recognition	1.68, 4.01, 7.00, 10.01, 12.46
Temperature Range	-5 to 105 ºC
Temperature Resolution	0.1 ºC
Display	Custom LCD
Inputs	1 BNC, 1 pin tip, ATC, Power, RS232
Power Requirements	AC line, 110 V, 220 V or 240 V
Dimensions	313 (L) x 205 (W) x 74(H) mm

Plate (3.6). pH Meter.

Table (3.11). Specifications of EC Meter.

Origin of manufacture	USA
Model	ORION 105
Range	0 to 199.990
Resolution	0.1
Relative Accuracy	0.5% F S
Temperature Range	-5 to 105 ºC
Temperature Resolution	0.1 ºC
Display	Custom LCD
Inputs	NA
Power Requirements	9V Battery, AC line, 110 V, 220 V or 240 V
Dimensions	190 x 80 x 50 mm

Plate (3.7). EC Meter.

3.2. Methods:

3.2.1. Water quality for intensive fish farming:

Water quality is widely acknowledged to be one of the most important rearing conditions that can be managed to reduce disease exposure and stress in intensive fish culture. However, the physiological tolerance of fish to water quality alterations is affected by a number of environmental and biological variables and it is not a simple matter to identify specific chemical constituents, temperature, or dissolved gas concentration that will provide optimum rearing conditions under all circumstances. First, the effects of water quality conditions on fish health very considerably with species, size, and age. Second, the water quality conditions themselves (particularly pH, dissolved oxygen, and temperature) can greatly alter the biological effect of dissolved substances. Water quality standards for intensive culture are presented in Table (3.12)

Table (3.12). Water quality standards recommended protecting the health of cold and warm-water fish in intensive culture.

Parameter	**Recommended Limits**
Acidity	pH 6 – 9
Arsenic	<0.05 mg/L
Alkalinity	10 – 400 mg/L
Aluminum	<0.075 mg/L
Ammonium (UN-ionized)	<0.02 mg/L
Cadmium	<0.0005mg/L in soft water; <0.005mg/L in hard water
Calcium	>5 mg/L
Carbon dioxide	<5 – 10 mg/L
Chloride	>4.0 mg/L
Chlorine	<0.003 mg/L
Copper	<0.0006mg/L in soft water <0.03 mg/L in hard water
Gas supersaturation	<110% total gas pressure
Hydrogen sulfide	<0.003 mg/L
Iron	<0.01 mg/L
Lead	<0.02 mg/L
Mercury	<0.02 mg/L
Nitrate	<3.0 mg/L
Nitrite	<0.1 mg/L
Dissolved Oxygen	5 mg/L, cold-water fish 3 mg/L, warm-water fish
Selenium	<0.01 mg/L
Total Dissolved Solids	<200 mg/L
Total Suspended Solids	<80 mg/L
Turbidity	<20 NTU over ambient level
Zinc	<0.005 mg/L

Source: Lawson, 1995

3.2.2. Treatments:

Eighteen treatments were applied:

- Two sources of nutrient were used:

(1) Stock nutrient solution

(2) Water discharged of the fish farm

- Three lengths of gully 2, 3 and 4 m
- Three water flow rates 1, 1.5 and 2 lit min^{-1}

3.2.3. Feed Management:

In feeding the fish, the recommendations of **Rakocy (1989)** were used as show in table (3.13). The feed pellet diameter was prepared according to the recommendation of **Jauncey and Ross (1982)** as shown in table (3.14). There was no feeding on the days of fish weighing.

Table (3.13). Recommended feeding rates for different size groups of tilapia in tanks and estimated growth rates at 28 °C.

Weight (g)		Growth Rate	Growth Period	Feeding Rate
Initial	Final	(g/day)	(day)	%
0.02	0.5 – 1	-	30	15 – 20
0.5 – 1	5	-	30	10 – 15
5	20	0.5	30	7 -10
20	50	1.0	30	4 – 7
50	100	1.5	30	3.5 – 4
100	250	2.5	50	1.5 – 3.5
250	450	3.0	70	1.0 – 1.5

Table (3.14). Recommended pellet size for tilapia.

Fish size (g)	Pellet diameter (mm)
Fry: first 24 hr	Liquefy
Fry: 2nd – 10th day	0.5
Fry: 10th – 30th day	0.5 – 1.0
1 -30	1 – 2
20 – 120	2
100 – 250	2
> 250	4

3.2.4. Lettuce Germination:

Lettuce seeds were sown on 4/2/2006 in peatmoss on the pots (5cm diameter and 5cm height). The pots were watered daily using water with **Hoagland and Arnon** solution. The small plants remained in the nursery until 16/ 3/ 2006 then they were removed carefully and settled in a continuously flowing nutrient solution in the gully. The plant spacing on the row was 20 cm **(Fahim, 1989).**

3.2.5. Sampling and Measurements:

3.2.5.1. Water Sampling:

Water samples were taken, at inlet and outlet of the hydroponic units for measuring ammonia (NH_3), nitrite (No_2), nitrate (No_3), Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) were measured every four days during the experimental period. pH and EC were measured directly in the field, weekly during the experimental period. Ammonia (NH_3) was measured by a speckol 11(table 3.6 and plate 3.2). Nitrite (No_2) and nitrate (No_3) were measured by ISE/pH Meters (table 3.7 and plate 3.3). Phosphorus (P) was measured by a spectrophotometer (table 3.8 and plate 3.4). Potassium (K) was measured by flame photometer (table 3.9 and plate 3.5). Calcium (Ca) and magnesium (Mg) were measured by using disodium versenate method as described by **Black (1965).** The pH was measured by the pH meter (table 3.10 and plate 3.6). The EC was measured by the EC meter (table 3.11 and plate 3.7).

3.2.5.2. Plant Sampling:

I- Root:

Root length was measured every ten days. To study the behavior of root growth, their mass production and assess to which extent there roots could be grown in the growing solution.

II- Yield:

The fresh and dry weight were measured at the end of the experiment. After measured fresh weight the plants were oven dried at 70 ºC until constant weight was reached.

III- Total nutrients uptake:

Total content of macro elements were evaluated after being digested according to **Chapman and Partt (1961).** Nitrogen (N) content was determined by using semi-micro Kjeldahl method. Phosphorus (P) was measured by a spectrophotometer. Potassium (K) was measured by flame photometer. Calcium (Ca) and Magnesium (Mg) were measured by using disodium versenate method as described by **(Black, 1965).**

IV- Nitrate uptake:

The nitrate was evaluated after being digested according to **Chapman and Partt (1961).** Nitrate (No_3) content was measured by using salsalic acid as described by **Chapman and Partt (1961).**

V- protein:

Protein was calculated from total nitrogen (N) by using the following relation

Protein = 6.25 * Total N

VI- No_3/Protein ratio;

No_3/ Protein ratio was calculated from dividing NO_3 by Protein

3.2.6. Calculation of nutrient concentration:

The ammonia consumption was calculated as the differences between the ammonia at inlet and outlet of hydroponic units by the following formula:

$$C_{NH3} = 60 \times \frac{NH_{3in} - NH_{3out}}{\text{No. of plants}} \times Q$$

Where: C_{NH3} = ammonia consumption, mg/h

$NH_{3\ in}$ = ammonia at inlet of the hydroponic unit, mg/L

$NH_{3\ out}$ = ammonia at outlet of the hydroponic unit, mg/L

Q = discharge, L/min

Nitrate consumption was calculated based on the differences between the nitrate at inlet and outlet of the hydroponic unit by the following formula:

$$C_{No3} = 60 \times \frac{NQ_{3in} - NO_{3out}}{\text{No. of plants}} \times Q$$

Where: C_{No3} = nitrate consumption, mg/h

$NO_{3\ in}$ = nitrate at inlet of hydroponic unit, mg/L

$NO_{3\ out}$ = nitrate at outlet of hydroponic unit, mg/L

Nitrite consumption was calculated based on the differences between the nitrite at inlet and outlet of the hydroponic unit by the following formula:

$$C_{No2} = 60 \times \frac{NQ_{2in} - NO_{2out}}{\text{No. of plants}} \times Q$$

Where: **C_{No2} = nitrite consumption, mg/h**

$NO_{2\ in}$ = nitrite at inlet of hydroponic unit, mg/L

$NO_{2\ out}$= nitrite at outlet of hydroponic unit, mg/L

Phosphorus consumption was calculated based on the differences between the phosphorus at inlet and outlet of the hydroponic unit by the following formula:

$$C_P = 60 \times \frac{P_{in} - P_{out}}{\text{No. of plants}} \times Q$$

Where: C_P = Phosphorus consumption, mg/h

P_{in} = Phosphorus at inlet of hydroponic unit, mg/L

P_{out}= Phosphorus at outlet of hydroponic unit, mg/L

Potassium consumption was calculated based on the differences between the potassium at inlet and outlet of the hydroponic unit by the following formula:

$$C_K = 60 \times \frac{K_{in} - K_{out}}{\text{No. of plants}} \times Q$$

Where: K C = Potassium consumption, mg/h

K_{in} = Potassium at inlet of hydroponic unit, mg/L

K_{out}= Potassium at outlet of hydroponic unit, mg/L

Calcium consumption was calculated based on the differences between the calcium at inlet and outlet of the hydroponic unit by the following formula:

$$\frac{Ca_{in} - Ca_{out}}{\text{No. of plants}}$$

$$C_{Ca} = 60 \times \qquad\qquad \times Q$$

Where: C_{Ca} = Calcium consumption, mg/h

Ca_{in} = Calcium at inlet of hydroponic unit, mg/L

Ca_{out}= Calcium at outlet of hydroponic unit, mg/L

Magnesium consumption was calculated based on the differences between the magnesium at inlet and outlet of the hydroponic unit by the following formula:

$$C_{Mg} = 60 \times \frac{Mg_{in} - Mg_{out}}{\text{No. of plants}} \times Q$$

Where: C_{Mg} = Magnesium consumption, mg/h

Mg_{in} = Magnesium at inlet of hydroponic unit, mg/L

Mg_{out}= Magnesium at outlet of hydroponic unit, mg/L

4- RESULTS AND DISCUSSION

4.1. Nutrient Consumption:

Any removal of nutrients from the solution can be equated with uptake by plants, provided that the system is free from leaks, algae and regardless of precipitation.

4.1.1. Effect of flow rate on nutrient consumption:

Tables (4.1A and B) and figures (4.1A, B, C, D and E) show the N, P, K, Ca and Mg consumption as mg.plant^{-1}.hour^{-1} for all treatments. There were changes in consumption of these nutrients during the growing period of lettuce plants. The rate of nutrients consumption in treatment of water discharged from the fish farm increase slowly with plant age. With enhanced concentration nutrient solution the nutrients consumption tends to increase more with plant age at different treatment.

The rate of nutrients consumption was decreased with increasing the flow rate. For example, N consumption decreased from 0.210 to 0.173 mg.plant^{-1}.hour^{-1} (17.6%) in nutrient solution and decreased from 0.160 to 0.147 mg.plant^{-1}.hour^{-1} (8.13%) in water discharged from the fish farm at 1 and 2 lit min^{-1} flow rate, respectively.

The lowest values of plant consumption were found in treatment of water discharged from the fish farm at a flow rate of 2 lit.min^{-1} and the highest values were found at a flow rate of 1 lit.min^{-1}. While, the lowest values of plant consumption were found in treatment of nutrient solution at a flow rate of 2 lit.min^{-1} and the highest values were found at a flow rate of 1 lit min^{-1}. Increasing the velocity of water in gullies with increasing the flow rate was decreased the rate of nutrients consumption. These results were in agreement with **(Graves and Hurd, 1983; Guibali, 1990; Rackocy et al., 1993; Rackocy et al., 1997)**.

The low consumption of N, P, K, Ca and Mg were observed in figures (4.1A, B, C, D and E) respectively after about 24 days from transplanting. It is may be associated with the root death period. **(Cooper, 1979)** found low consumption of N and Cu during the death period. while, the highest nutrients consumption were obtained after about 32 days from transplanting.

Table (4.1A): Effect of flow rate (l min^{-1}) on nutrients consumption as mg plant^{-1} hour^{-1} in nutrient solution.

Day	N			P			K			Ca			Mg		
	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0
20/3	0.040	0.033	0.032	0.037	0.033	0.029	0.091	0.082	0.073	0.037	0.037	0.029	0.029	0.027	0.016
24/3	0.112	0.115	0.109	0.037	0.033	0.029	0.149	0.142	0.124	0.054	0.048	0.048	0.069	0.055	0.044
28/3	0.210	0.190	0.173	0.054	0.048	0.046	0.200	0.185	0.173	0.109	0.093	0.080	0.186	0.163	0.153
1/4	0.218	0.202	0.202	0.062	0.060	0.051	0.214	0.197	0.182	0.120	0.103	0.102	0.211	0.202	0.182
5/4	0.266	0.247	0.227	0.069	0.060	0.064	0.330	0.322	0.304	0.149	0.142	0.138	0.266	0.245	0.224
9/4	0.229	0.218	0.198	0.054	0.048	0.044	0.266	0.247	0.227	0.109	0.103	0.102	0.186	0.163	0.153
13/4	0.277	0.257	0.224	0.069	0.060	0.058	0.464	0.435	0.407	0.123	0.103	0.109	0.248	0.230	0.218
17/4	0.371	0.355	0.329	0.091	0.082	0.080	0.626	0.617	0.604	0.186	0.163	0.167	0.371	0.355	0.329
21/4	0.283	0.278	0.269	0.069	0.060	0.064	0.461	0.448	0.444	0.174	0.168	0.160	0.261	0.250	0.247
25/4	0.283	0.278	0.269	0.054	0.055	0.051	0.454	0.448	0.444	0.157	0.148	0.147	0.259	0.257	0.240
29/4	0.330	0.322	0.304	0.069	0.072	0.064	0.454	0.497	0.480	0.149	0.142	0.124	0.323	0.322	0.304
3/5	0.323	0.322	0.304	0.054	0.055	0.051	0.461	0.458	0.444	0.168	0.153	0.153	0.196	0.202	0.189
5/5	0.330	0.322	0.304	0.054	0.055	0.051	0.461	0.442	0.429	0.174	0.168	0.160	0.196	0.202	0.189

Table (4.1B): Effect of flow rate (l min^{-1}) on nutrients consumption as mg plant^{-1} hour^{-1} in water discharged from the fish farm.

Day	N			P			K			Ca			Mg		
	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0	1.0	1.5	2.0
20/3	0.041	0.034	0.009	0.018	0.022	0.016	0.054	0.048	0.044	0.018	0.022	0.016	0.014	0.022	0.016
24/3	0.105	0.090	0.096	0.018	0.022	0.029	0.091	0.082	0.073	0.022	0.022	0.029	0.040	0.033	0.036
28/3	0.160	0.156	0.147	0.022	0.022	0.029	0.109	0.103	0.080	0.037	0.033	0.029	0.131	0.115	0.109
1/4	0.190	0.196	0.179	0.037	0.033	0.036	0.120	0.103	0.102	0.037	0.033	0.044	0.170	0.152	0.138
5/4	0.202	0.217	0.208	0.040	0.030	0.036	0.186	0.175	0.160	0.078	0.048	0.044	0.211	0.202	0.189
9/4	0.173	0.161	0.148	0.030	0.030	0.029	0.146	0.137	0.121	0.024	0.033	0.030	0.134	0.115	0.109
13/4	0.208	0.215	0.199	0.037	0.030	0.029	0.266	0.257	0.240	0.054	0.038	0.044	0.186	0.163	0.153
17/4	0.285	0.267	0.258	0.054	0.048	0.044	0.337	0.322	0.304	0.109	0.103	0.102	0.269	0.262	0.240
21/4	0.234	0.215	0.201	0.040	0.033	0.036	0.252	0.252	0.233	0.094	0.067	0.087	0.214	0.202	0.199
25/4	0.219	0.215	0.206	0.037	0.030	0.036	0.243	0.235	0.233	0.077	0.073	0.064	0.192	0.174	0.189
29/4	0.251	0.239	0.239	0.037	0.030	0.036	0.280	0.278	0.269	0.069	0.060	0.064	0.226	0.217	0.209
3/5	0.244	0.239	0.231	0.037	0.030	0.036	0.266	0.257	0.262	0.083	0.077	0.073	0.149	0.142	0.144
5/5	0.217	0.200	0.199	0.037	0.030	0.036	0.259	0.252	0.233	0.094	0.103	0.102	0.149	0.142	0.144

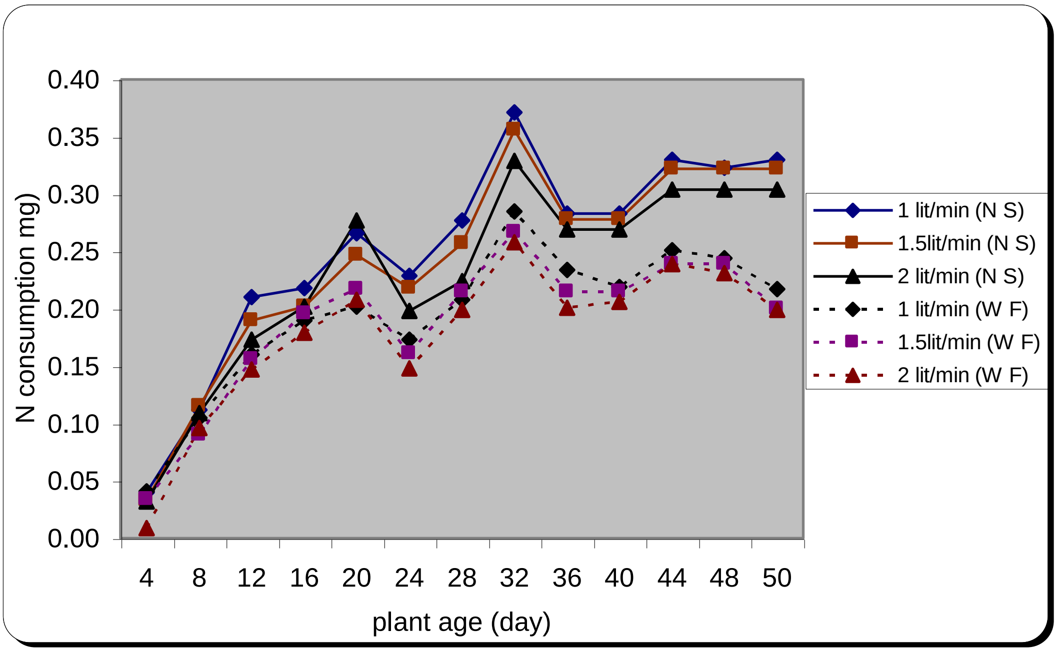

Fig. (4.1A): Effect of flow rate on N consumption (mg plant^{-1} hour^{-1})

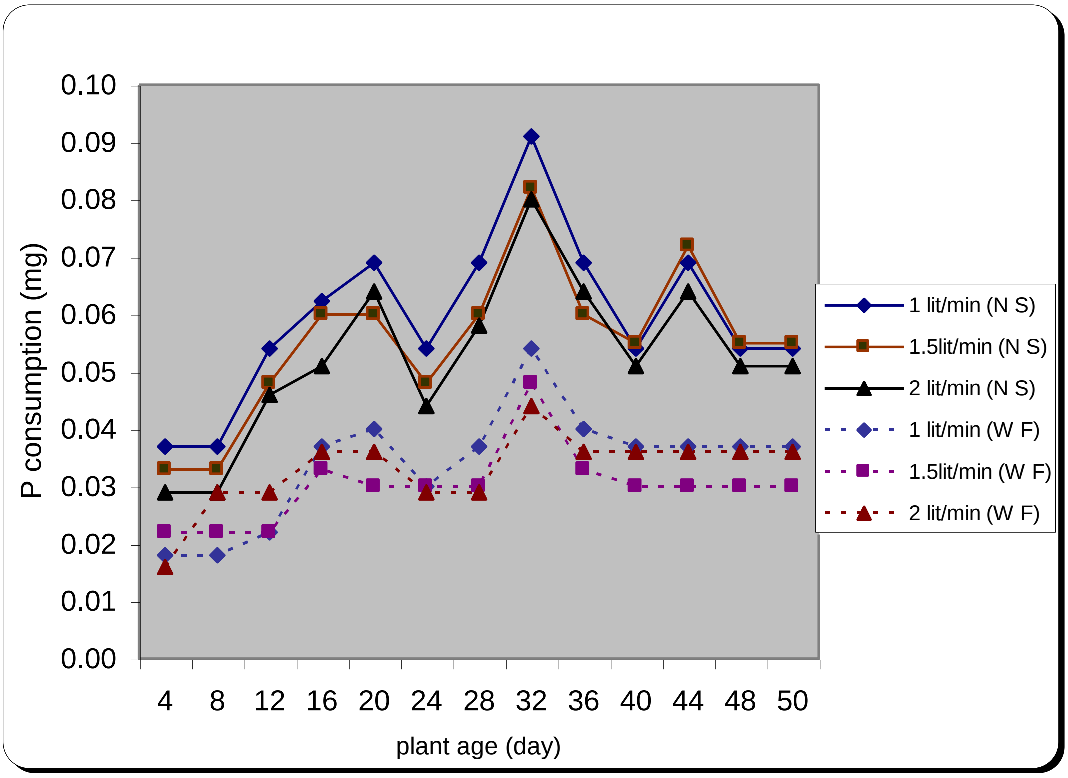

Fig. (4.1B): Effect of flow rate on P consumption (mg plant^{-1} hour^{-1})

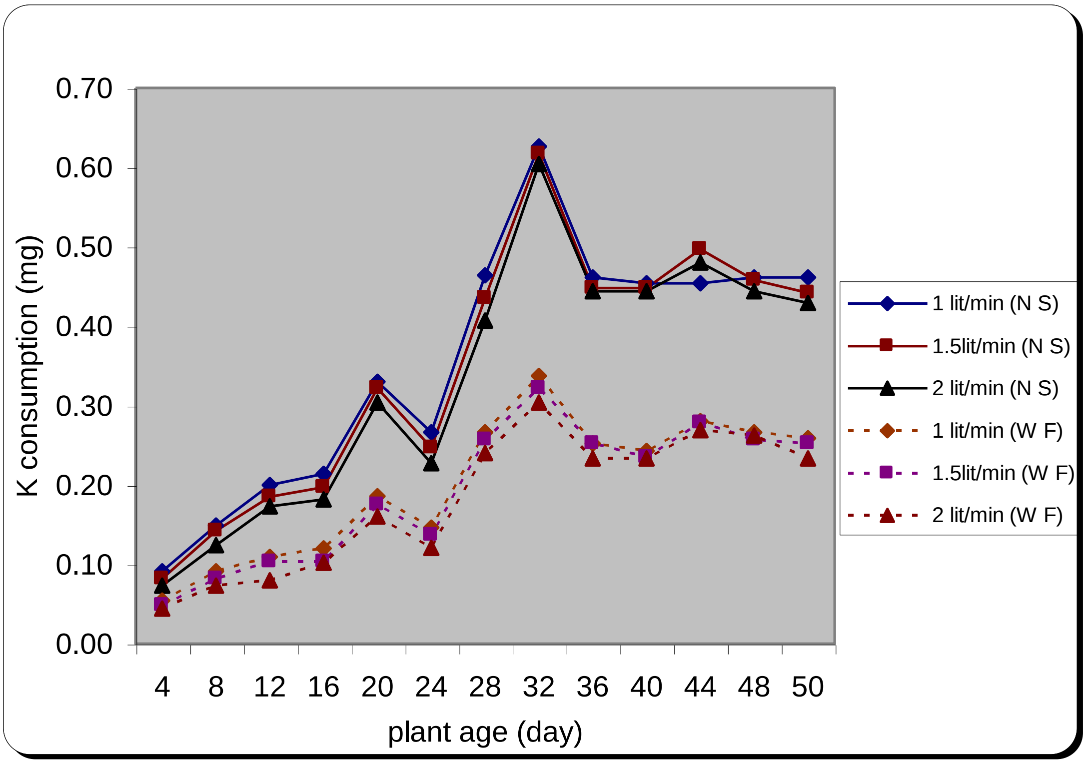

Fig. (4.1C): Effect of flow rate on K consumption (mg plant^{-1} hour^{-1})

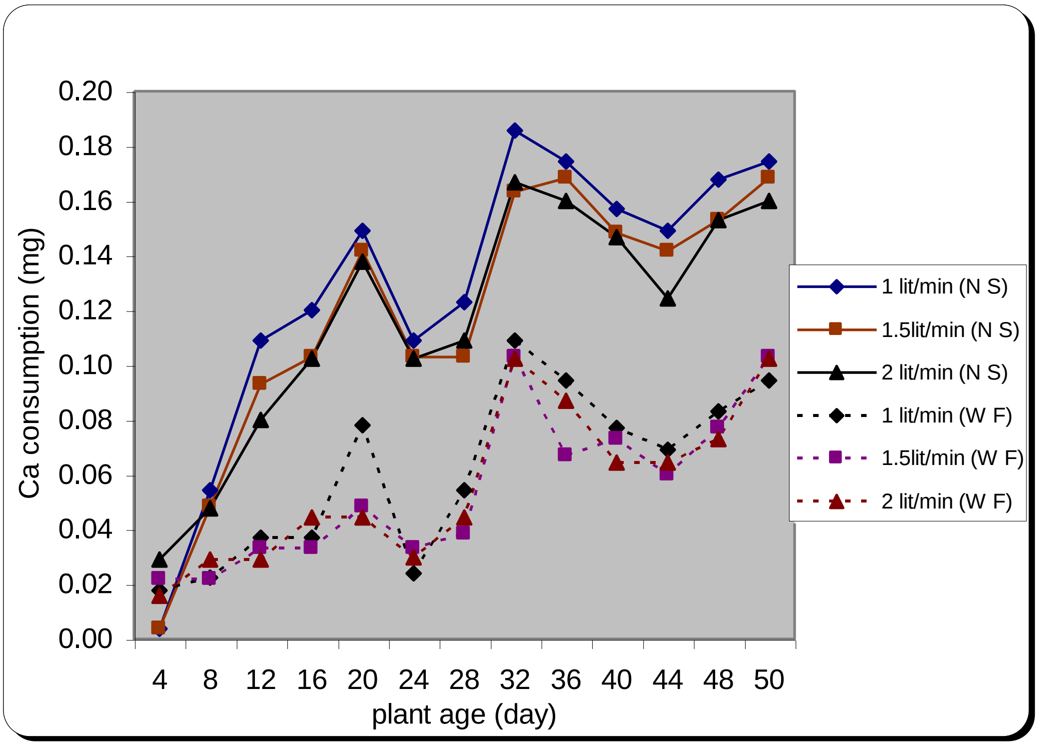

Fig. (4.1D): Effect of flow rate on Ca consumption (mg plant^{-1} hour^{-1})

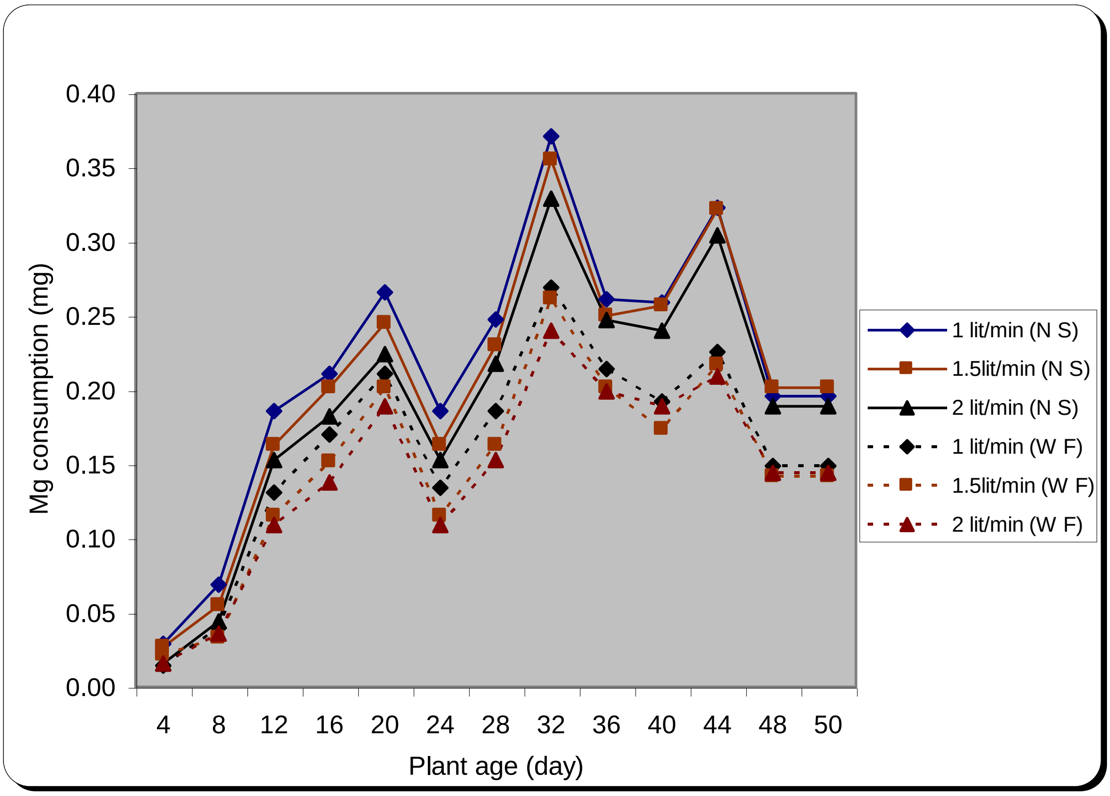

Fig. (4.1E): Effect of flow rate on Mg consumption (mg plant^{-1} hour^{-1})

4.1.2. Effect of length of gully on nutrient consumption:

Tables (4.2A and B) and figures (4.2A, B, C, D and E) show the N, P, K, Ca and Mg consumption as mg.plant^{-1}.hour^{-1} for all treatments. The rate of nutrients consumption was decreased with increasing the length of gully. For example, N consumption decreased from 0.270 to 0.213 mg plant^{-1} hour^{-1} (about 21.1%) in nutrient solution and decreased from 0.230 to 0.188 mg plant^{-1} hour^{-1} (about 18.3%) in water discharged from the fish farm at 2 and 4 m length of gully, respectively.

The lowest values of plant consumption were found in treatment of water discharged form the fish farm a length of gully 4 m and the highest values were found at a length of gully 2m. While, the lowest values of plant consumption were found in treatment of nutrient solution a length of gully 4 m and the highest values were found at a length of gully 2m. Worthy to note that pumping either nutrient solution or water discharged from the fish farm to the growing gully was adjusted as 1 min pumping and 4 min rest. This was performed with 1 and 2 lit discharge in 2 – 4 m of the gully. Thus, the nutrients stayed longer under the 4 m length and the total intake of nutrients were longer than that achieved with the shorter gully (2 m). The refreshment of nutrients under the longer gullies were restricted as compared with the shorter gullies.

Table (4.2A): Effect of length of gully on nutrients consumption as mg plant^{-1} hour^{-1} in nutrient solution.

Day	N			P			K			Ca			Mg		
	2 m	3 m	4 m	2 m	3 m	4 m	2 m	3 m	4 m	2 m	3 m	4 m	2 m	3 m	4 m
20/3	0.033	0.036	0.037	0.037	0.036	0.027	0.090	0.084	0.072	0.037	0.036	0.027	0.023	0.025	0.023
24/3	0.120	0.111	0.105	0.037	0.036	0.027	0.143	0.140	0.132	0.053	0.049	0.048	0.060	0.060	0.048
28/3	0.217	0.180	0.177	0.053	0.049	0.045	0.210	0.180	0.169	0.097	0.096	0.090	0.180	0.169	0.153
1/4	0.230	0.200	0.192	0.053	0.060	0.060	0.217	0.200	0.177	0.127	0.109	0.090	0.227	0.200	0.168
5/4	0.270	0.246	0.213	0.073	0.060	0.060	0.330	0.314	0.312	0.157	0.140	0.132	0.263	0.240	0.232
9/4	0.233	0.220	0.192	0.053	0.049	0.045	0.270	0.256	0.213	0.120	0.105	0.090	0.180	0.169	0.153
13/4	0.270	0.251	0.237	0.053	0.049	0.045	0.480	0.424	0.402	0.133	0.109	0.100	0.253	0.235	0.213
17/4	0.353	0.360	0.342	0.090	0.084	0.078	0.623	0.620	0.603	0.193	0.169	0.153	0.353	0.360	0.342
21/4	0.293	0.276	0.262	0.073	0.060	0.060	0.457	0.440	0.435	0.173	0.164	0.165	0.277	0.244	0.237
25/4	0.293	0.314	0.312	0.053	0.055	0.052	0.503	0.496	0.483	0.157	0.160	0.135	0.257	0.256	0.243
29/4	0.330	0.314	0.312	0.083	0.067	0.055	0.503	0.496	0.483	0.143	0.140	0.132	0.323	0.314	0.312
3/5	0.322	0.314	0.312	0.053	0.055	0.052	0.467	0.455	0.442	0.163	0.164	0.147	0.203	0.191	0.192
5/5	0.330	0.314	0.312	0.053	0.055	0.052	0.457	0.440	0.435	0.173	0.164	0.165	0.203	0.191	0.192

Table (4.2B): Effect of length of gully on nutrients consumption as mg plant^{-1} hour^{-1} in water discharged from the fish farm.

Day	N			P			K			Ca			Mg		
	2 m	3 m	4 m	2 m	3m	4 m	2m	3 m	4 m	2 m	3 m	4 m	2 m	3 m	4 m
20/3	0.026	0.028	0.030	0.017	0.020	0.018	0.053	0.049	0.045	0.017	0.020	0.018	0.017	0.020	0.015
24/3	0.106	0.089	0.092	0.030	0.020	0.018	0.090	0.084	0.072	0.030	0.025	0.018	0.037	0.036	0.037
28/3	0.167	0.154	0.149	0.030	0.025	0.018	0.107	0.096	0.090	0.037	0.036	0.027	0.127	0.120	0.108
1/4	0.200	0.195	0.172	0.037	0.036	0.033	0.133	0.109	0.090	0.037	0.044	0.033	0.180	0.144	0.135
5/4	0.230	0.215	0.188	0.037	0.032	0.033	0.180	0.176	0.165	0.053	0.049	0.045	0.210	0.200	0.192
9/4	0.183	0.154	0.144	0.030	0.032	0.027	0.143	0.140	0.120	0.037	0.036	0.027	0.127	0.120	0.112
13/4	0.224	0.200	0.196	0.037	0.032	0.033	0.263	0.256	0.243	0.043	0.049	0.045	0.180	0.169	0.153
17/4	0.288	0.265	0.256	0.053	0.049	0.045	0.337	0.314	0.312	0.120	0.105	0.090	0.263	0.256	0.252
21/4	0.230	0.218	0.202	0.037	0.036	0.037	0.257	0.256	0.255	0.090	0.084	0.087	0.213	0.200	0.202
25/4	0.230	0.204	0.212	0.037	0.032	0.033	0.293	0.276	0.258	0.073	0.080	0.063	0.193	0.178	0.183
29/4	0.254	0.240	0.242	0.053	0.036	0.037	0.293	0.276	0.258	0.073	0.060	0.060	0.240	0.205	0.207
3/5	0.248	0.235	0.232	0.037	0.032	0.033	0.277	0.265	0.243	0.090	0.080	0.063	0.157	0.140	0.138
5/5	0.220	0.200	0.197	0.037	0.032	0.033	0.263	0.256	0.225	0.090	0.084	0.087	0.157	0.140	0.138

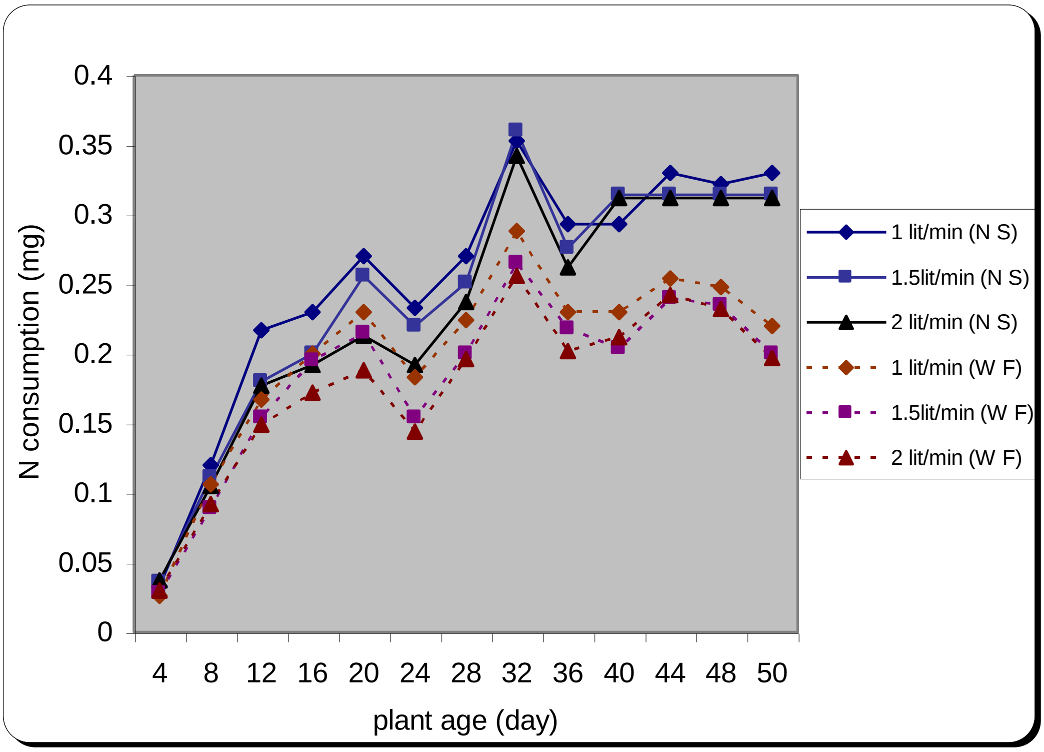

Fig. (4.2A): Effect of length of gully on N consumption (mg plant^{-1}hour^{-1})

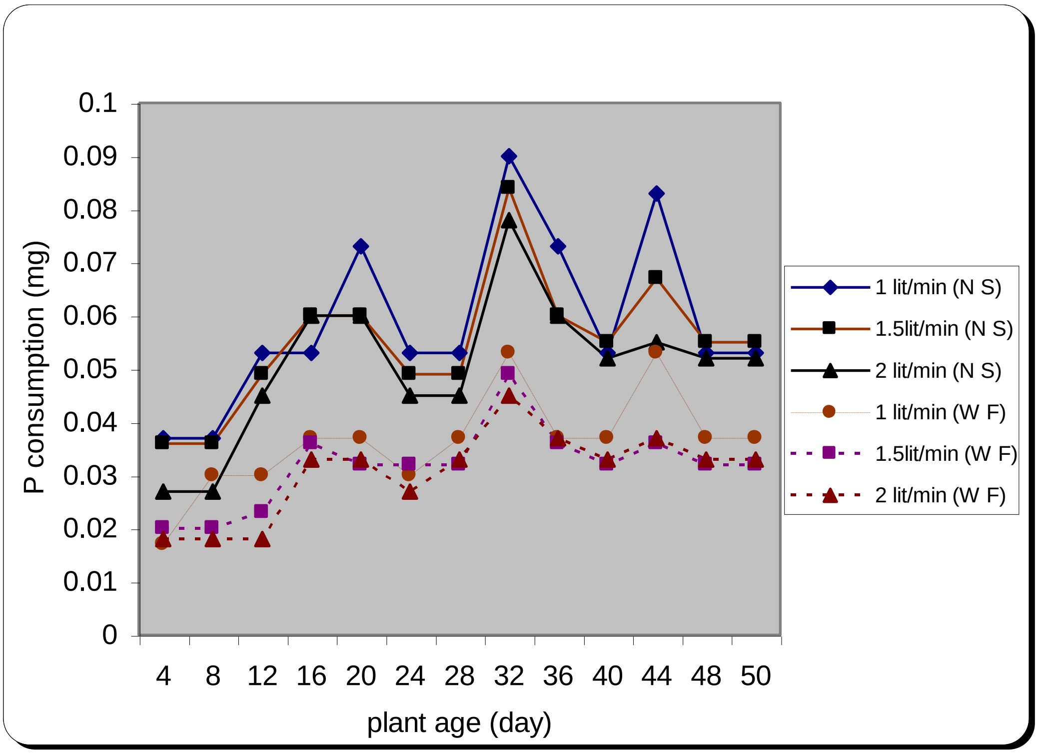

Fig. (4.2B):Effect of length of gully on P consumption (mg plant^{-1} hour^{-1})

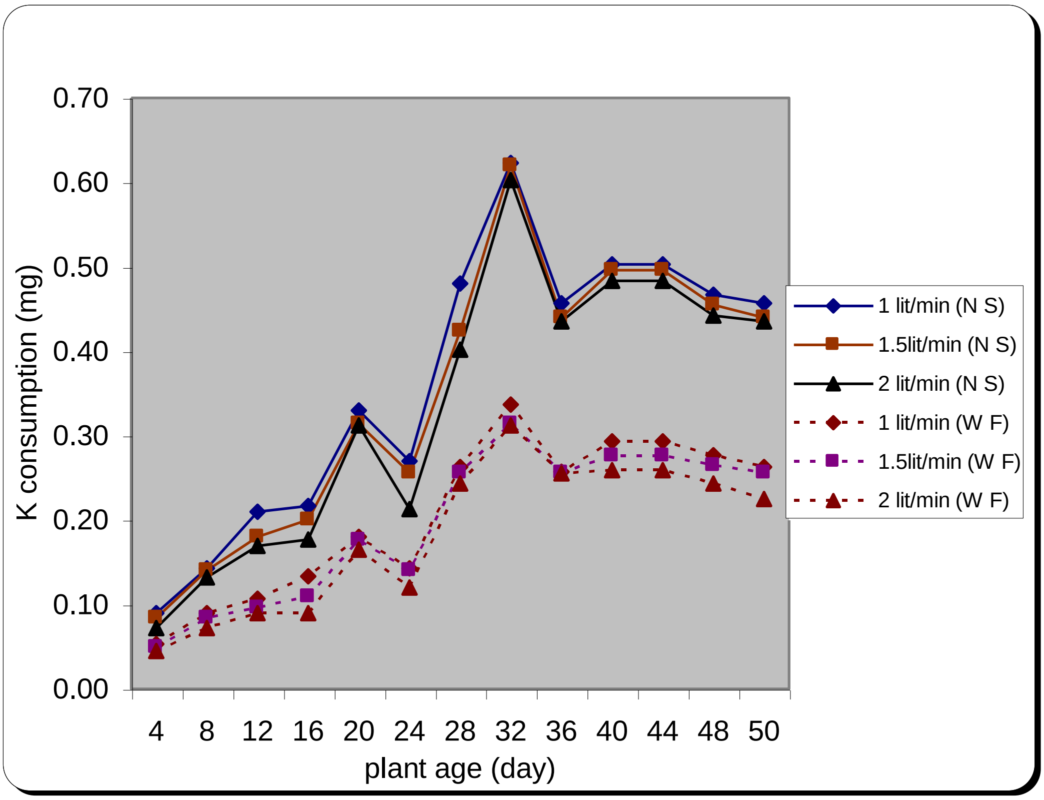

Fig. (4.2C): Effect of length of gully on K consumption (mg plant^{-1}hour^{-1})

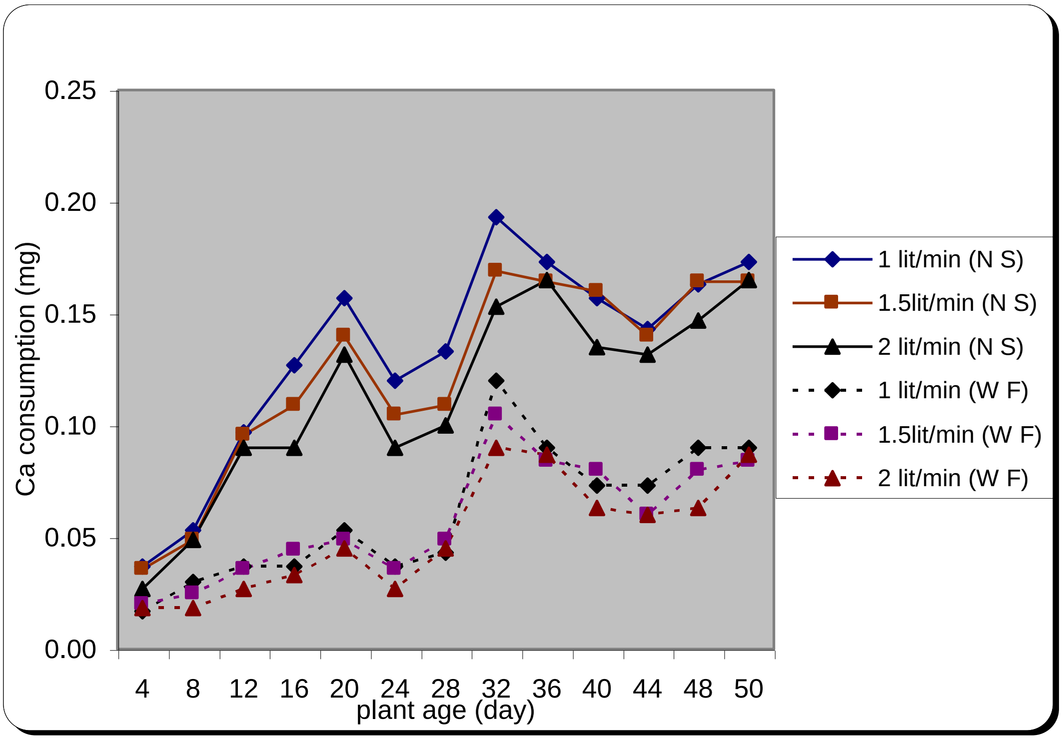

Fig.(4.2D):Effect of length of gully on Ca consumption(mg plant^{-1} hour^{-1})

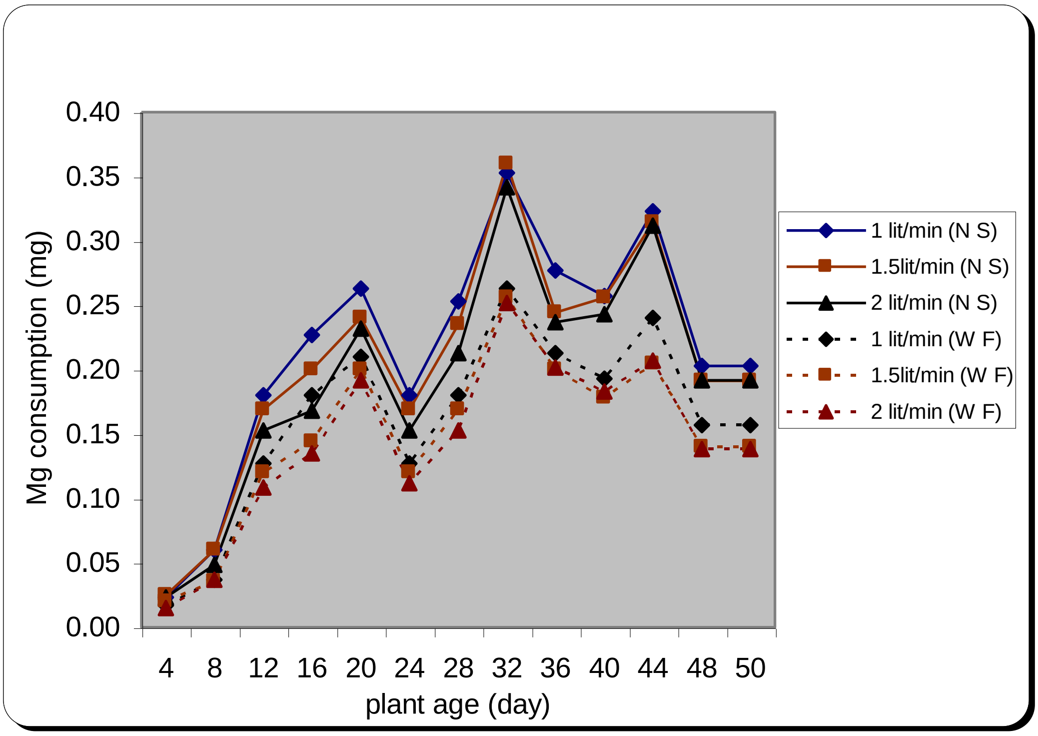

Fig.(4.2E): Effect of length of gully on Mg consumption(mg plant^{-1}hour^{1})

4.2. pH

During the investigation pH fluctuated between 7.4 and 7.9 in the water discharged from the fish farm and between 6.5 and6.8 in the nutrient solution.

4.3. EC

During the investigation EC fluctuated between 1.00 and 1.45 ds/m in the water discharged from the fish farm and between 1.13 and 2.09 ds/m in the nutrient solution.

4.4. The length of root:

4.4.1. Effect of flow rate on the length of root:

Table (4.3) and figure (4.3) show the length of root for all treatments. The length of root was increased with increasing the flow rate. For example, the length of root increased from 9.43 to 10.33 cm after 20 days from transplanting (8.7%) in nutrient solution and increased from 10.37 to 11.00 cm after 20 days from transplanting (5.7%) in water discharged of the fish farm at 1 and 2 lit min^{-1} flow rate, respectively. It was noticed that there was not any overlapping (interference) between roots of the growing plants as a result of choosing a suitable distance (20 cm) apart between plants during different growth stages. If there is any overlapping existed it was very limited (not more than 3.0%).

The highest value of the length of root (20.63 cm) was found with waste fish farm. However, the lowest value was found to be (19.50 cm) with nutrient solution. Data of the length of roots tended to faviour high value of fresh weight which associated with the highest root length (20.00 cm). These results were in agreement with **Van Os (1983)** and **Benoit (1987)** found that the plant spacing for lettuce was (20-25 cm) and **Fahim (1989)** mentioned that the plant spacing for lettuce was 20 cm.

Table (4.3): Effect of flow rate on the length of root

day	Nutrient Solution			Water Fish Farm		
	1 lit/min	1.5 lit/min	2 lit/min	1 lit/min	1.5 lit/min	2 lit/min
26/3	4.27	4.43	5.43	4.77	5.17	5.60
5/4	9.43	9.60	10.33	10.37	10.80	11.00
15/4	14.80	15.27	15.83	15.77	16.37	16.73
25/4	17.47	17.87	18.10	18.07	18.13	18.57
5/5	19.50	19.73	20.00	19.97	20.23	20.63

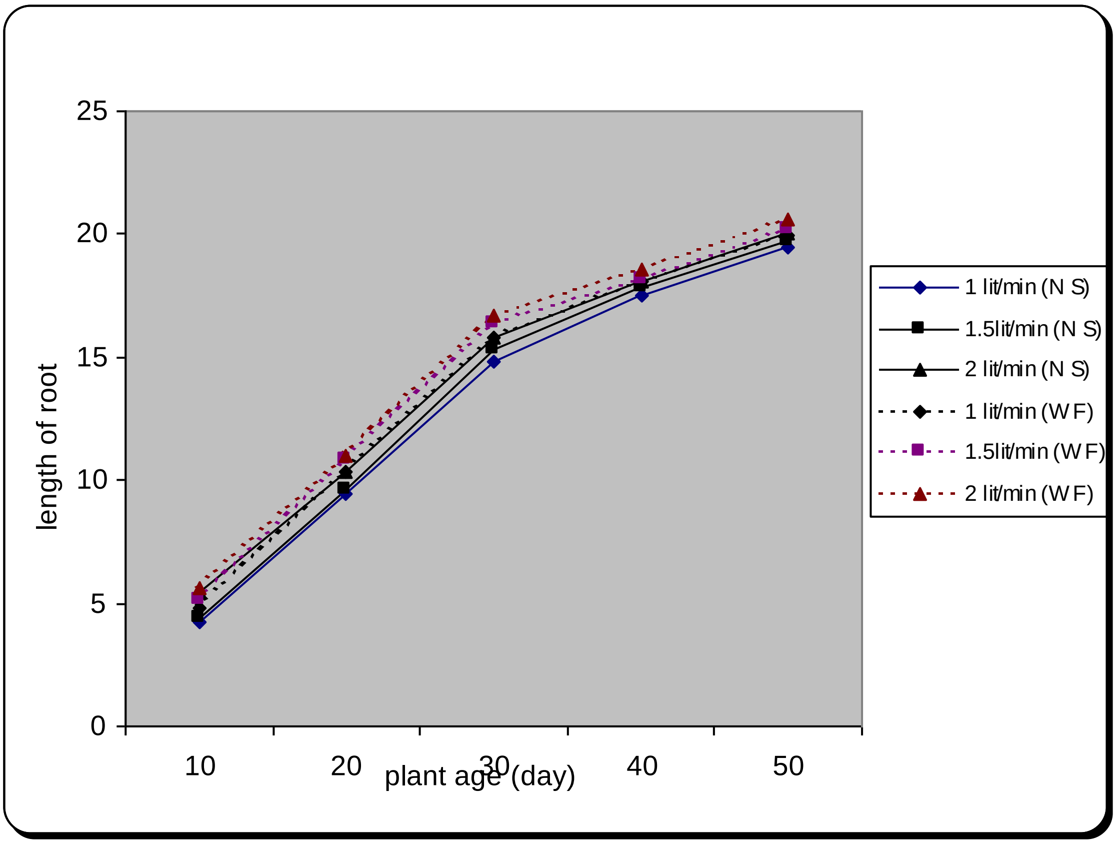

Fig. (4.3): Effect of flow rate on the length of root

4.4.2. Effect of length of gully on the length of root:

Table (4.4) and figure (4.4) show the length of root for all treatments. The length of root was increased with increasing the length of gully. For example, the length of root increased from 17.43 to 18.33 cm after 40 days from transplanting (4.9%) in nutrient solution and increased from 17.87 to 18.60 cm after 40 days from transplanting (3.9%) in water discharged from the fish farm at 2 and 4 m length of gully, respectively. It was noticed that there was not any overlapping (interference) between roots of the growing plants as a result of choosing a suitable distance (20 cm) apart between plants during different growth stages. If there is any overlapping existed it was very limited (not more than 3.4%).

The highest value of the length of root (20.70 cm) was found with water discharged from the fish farm. However, the lowest value was found to be (19.47 cm) with nutrient solution. Data of the length of roots tended to faviour high value of fresh weight while associated with the highest root length (20.00 cm). These results were in agreement with **Van Os (1983)** and **Benoit (1987)** found that the plant spacing for lettuce was (20-25 cm) and **Fahim (1989)** mentioned that the plant spacing for lettuce was 20 cm.

Table (4.4): Effect of flow rate on the length of root

day	Nutrient Solution			Water Fish Farm		
	1 lit/min	1.5 lit/min	2 lit/min	1 lit/min	1.5 lit/min	2 lit/min
26/3	4.27	4.43	5.43	4.77	5.17	5.60
5/4	9.43	9.60	10.33	10.37	10.80	11.00
15/4	14.80	15.27	15.83	15.77	16.37	16.73
25/4	17.47	17.87	18.10	18.07	18.13	18.57
5/5	19.50	19.73	20.00	19.97	20.23	20.63

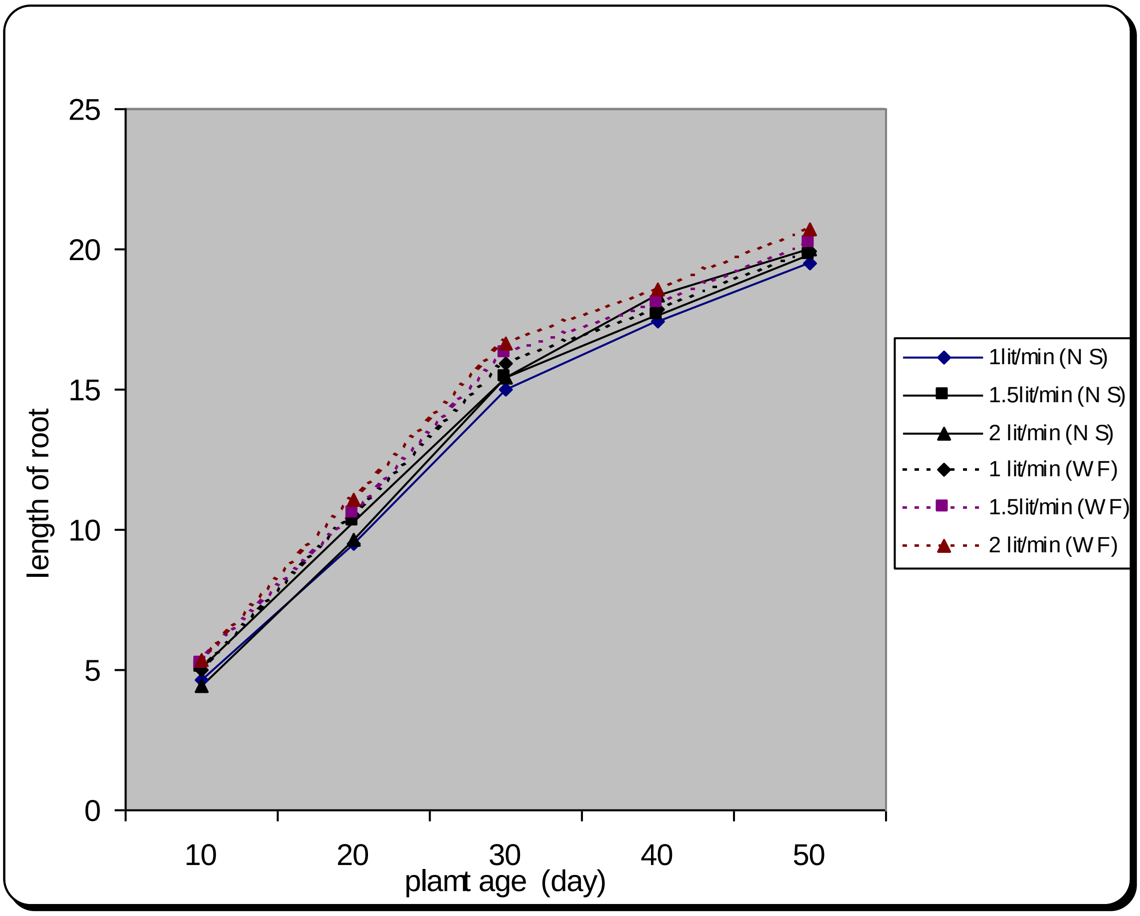

Fig. (4.4): Effect of flow rate on the length of root

4.5. Fresh and dry weight:

4.5.1. Fresh and dry weight of shoot:

Table (4.5) show the effect sources of nutrient, flow rates and lengths of gully on the fresh and dry weight production of lettuce plants at the end of growing period. The highest value of fresh weight 296.47 g.plant^{-1} was obtained at a flow rate of 2 lit.min^{-1} with 4 m length of gully. While, the lowest value of fresh weight 172 g.plant^{-1} was obtained at a flow rate of 1 lit.min^{-1} with 3 m length of gully in nutrient solution. On the other hand, the highest value of fresh weight 256.10 g plant^{-1} was found at a flow rate of 2 lit.min^{-1} with 4 m length of gully. While, the lowest value of fresh weight 132.10 g plant^{-1} was found at a flow rate of 1 lit.min^{-1} with 3 m length of gully in water discharged from the fish farm. The highest value of dry weight 28.96 g plant^{-1} was obtained at a flow rate of 2 lit min^{-1} with 4 m length of gully. While, the lowest value of dry weight 20.35 g plant^{-1} was obtained at a flow rate of 1.5 lit min^{-1} with 4 m length of gully in nutrient solution. On the other hand, the highest value of dry weight 25.90 g plant^{-1} was obtained at a flow rate of 1.5 lit.min^{-1} with 2 m length of gully. While, the lowest value of dry weight 17.36 g plant^{-1} was obtained at a flow rate of 1 lit min^{-1} with 4 m length of gully in water discharged from the fish farm.

The best flow rate for 2 m length of gully of 1.5 lit.min^{-1}. This result was in agreement with **Benoit and Ceustermans (1989)** and **Fahim (1989)**. The best flow rate for 3 m length of gully of 1.5 lit.min^{-1} and the best flow rate for 4m length of gully of 2 lit min^{-1}.

Table (4.5). Fresh and dry weight of shoot (g/ plant)

Length of gully	Nutrient Solution						Water Farm					
	1 lit/ min		1.5 lit/ min		2 lit/ min		1 lit/ min		1.5 lit/ min		2 lit/ min	
	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	Dry
2 m	183	22.10	293.65	28.40	276.05	26.12	145.09	18.46	248	25.90	233.60	24.88
3 m	172	21.72	234.83	26.38	215.13	22.35	132.10	20.67	197.60	19.71	167.11	20.64
4 m	233.83	17.94	277.83	20.35	296.47	22.96	201.44	17.36	203.19	19.33	256.10	22.53

4.5.1.1. Effect of flow rate on fresh and dry weight of shoot:

Table (4.6) and figures (4.5A and B) show the effect of flow rate on fresh and dry weight of shoot production of lettuce plants at the end of growing period. The fresh and dry weights were increased with increasing the flow rate. The fresh weight increased from 192.28 to 262.55 g plant^{-1} (t 26.76%) in nutrient solution and increased from 159.54 to 218.93g plant^{-1} (27.13%) in water discharged from the fish farm at 1 and 2 lit.min^{-1} flow rate, respectively. The dry weight increased from 22.25 to 25.81 g.plant^{-1} (13.79%) in nutrient solution and increased from 18.83 to 23.35 g.plant^{-1} (19.36%) in water discharged from the fish farm at 1 and 2 lit.min^{-1} flow rate, respectively. These results were in agreement with **(Fahim, 1989)** found that the dry weight increased with increasing the flow rate at 0.5 to 1.5 lit.hour^{-1}.

Table (4.6): Effect of flow rate on fresh and dry weight of shoot

Nutrient solution						Water fish farm					
1 lit/min		1.5 lit/min		2 lit/min		1 lit/min		1.5 lit/min		2 lit/min	
fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry
192.28	22.25	252.11	25.04	262.55	25.81	159.54	18.83	216.26	21.65	218.93	23.35

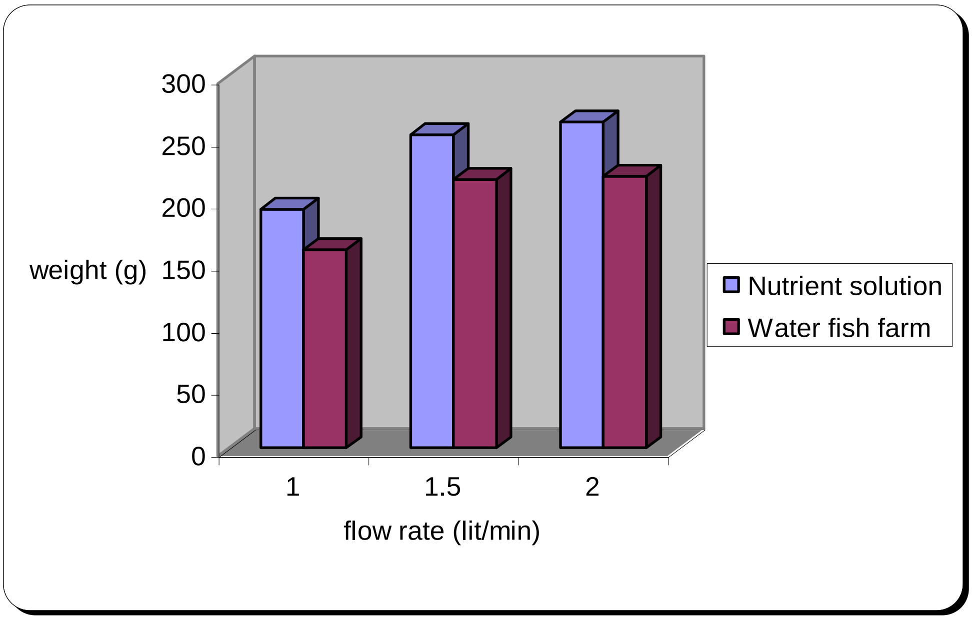

Fig. (4.5A): Effect of flow rate on fresh weight of shoot

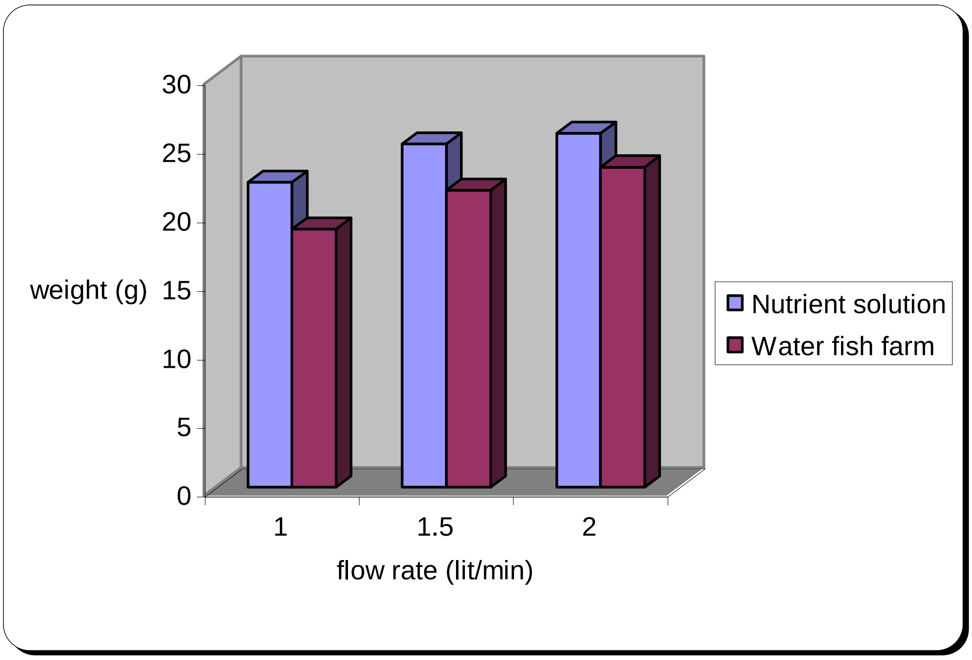

Fig. (4.5B): Effect of flow rate on dry weight of shoot

4.5.1.2. Effect of length of gully on fresh and dry weight of shoot:

Table (4.7) and figures (4.6A and B) show the effect of length of gully on fresh and dry weight of shoot production of the end of growing period. The fresh and dry weights were decreased with increasing the length of gully at 2 to 3 m. The fresh weight decreased from 250.90 to 207.32 g.plant^{-1} (17.37%) in nutrient solution and decreased from 208.90 to 165.60 g.plant^{-1} (20.73%) in water discharged from the fish farm. While, the dry weight decreased from 25.54 to 23.48 g.plant^{-1} (8.07%) in nutrient solution and decreased from 23.08 to 20.34 g.plant^{-1} (11.87%) in water discharged from the fish farm. However, the fresh and dry weights were increased with increasing the length of gully at 3 to 4 m. The fresh increased from 207.32 to 252.71 g.plant^{-1} (17.57%) in nutrient solution and increased from 165.60 to 220.24 g.plant^{-1} (24.81%) in water discharged from the fish farm. While, the dry weight increased from 23.48 to 24.08 g.plant^{-1} (2.49%) in nutrient solution and increased from 20.34 to 20.41 g.plant^{-1} (0.34%) in water discharged from the fish farm.

Table (4.7): Effect of length of gully on fresh and dry weight of shoot

Nutrient solution						Water fish farm					
2 m		3 m		4 m		2 m		3 m		4 m	
fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry
250.90	25.54	207.32	23.48	252.71	24.08	208.90	23.08	065.60	20.34	220.24	20.41

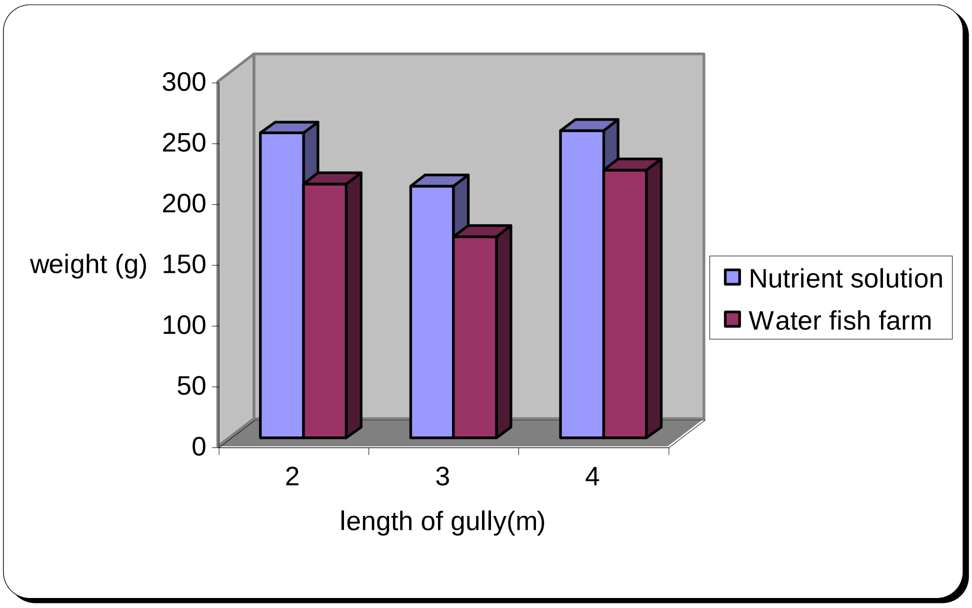

Fig. (4.6A): Effect of length of gully on fresh weight of shoot

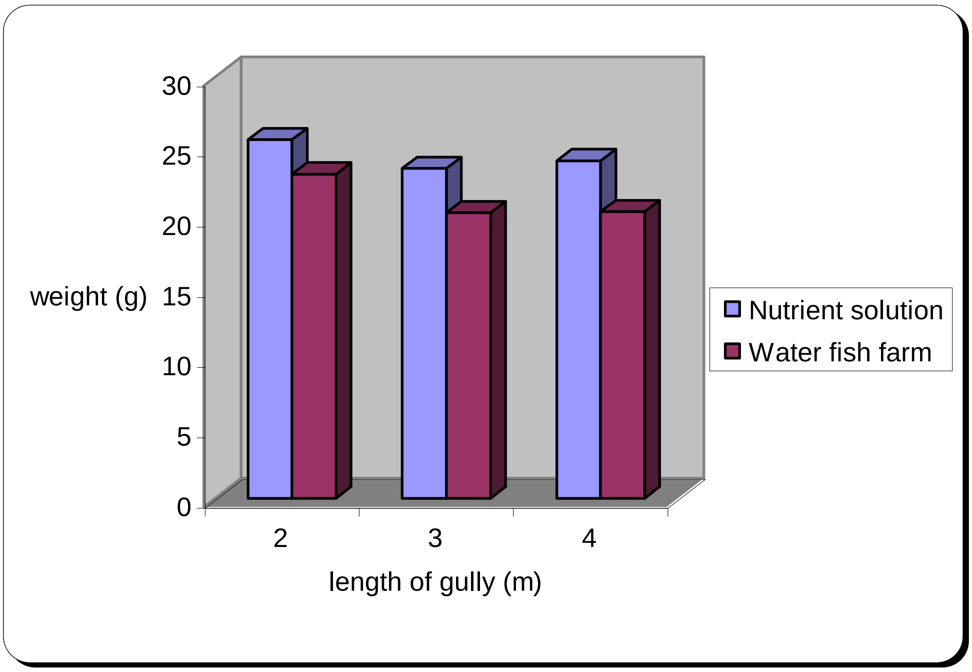

Fig.(4.6B): Effect of length of gully on dry weight of shoot

4.5.2. Fresh and dry weight of root:

4.5.2.1. Effect of flow rate on fresh and dry weight of root:

Table (4.8) and figures (4.7A and B) show the effect of flow rate on fresh and dry weight of root production of lettuce plants at the end of growing period. The fresh and dry weights of root were increased with increasing the flow rate at 1 to 1.5 lit.min^{-1}. The fresh weight increased from 82.06 to 100.63 g plant^{-1} (18.45%) in nutrient solution and increased from 68.35 to 92.37 g.plant^{-1} (26.00%) in water discharged from the fish farm. While, the dry weight increased from 6.15 to 8.91 g.plant^{-1} (30.98%) in nutrient solution and increased from 5.13 to 6.36 g.plant^{-1} (19.34%) in water discharged from the fish farm. However, the fresh and dry weights of root were decreased with increasing the flow rate at 1.5 and 2 lit.min^{-1} in nutrient solution. The fresh weight decreased from 100.63 to 86.13 g.plant^{-1} (14.41%). While, the dry weight decreased from 8.91 to 6.54 g.plant^{-1} (26.60%). On the other hand, the fresh and dry weights of root were increased with increasing the flow rate in water discharged of the fish farm. The fresh weight increased from 68.35 to 98.46 g.plant^{-1} (30.58%) at 1 and 2 lit min^{-1}, respectively. While, the dry weight increased from 5.13 to 7.75 g.plant^{-1} (33.81%) at 1 and 2 lit min^{-1}, respectively.

Furthermore, the fresh and dry weights of root were more in nutrient solution than in water discharged from the fish farm. This helps explain yield and growth of root differences from various solutions. Generally, the growth of root system of the plant in a solution has optimum conditions depending on the amount of nutrients available to the roots its oxygen supply, the osmotic pressure of solution and its temperature. These results were in agreement with **(Guibali, 1990)**.

Table (4.8): Effect of flow rate on fresh and dry weight of root

Nutrient solution						Water fish farm					
1 lit/min		1.5 lit/min		2 lit/min		1 lit/min		1.5 lit/min		2 lit/min	
fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry
82.15	6.15	100.63	8.91	86.13	6.35	68.35	5.13	92.37	6.38	98.46	7.75

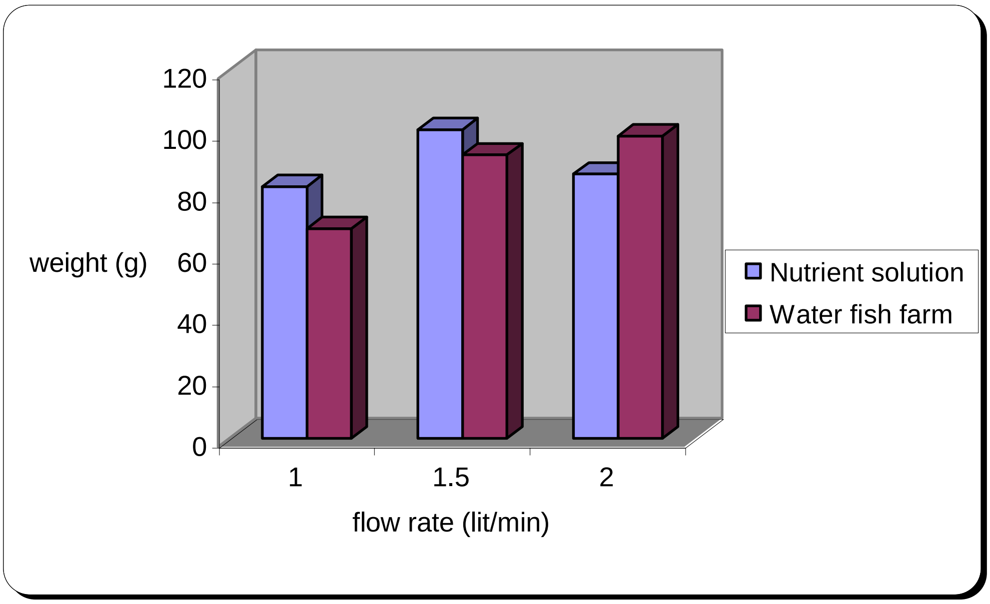

Fig. (4.7A): Effect of flow rate on fresh weight of root

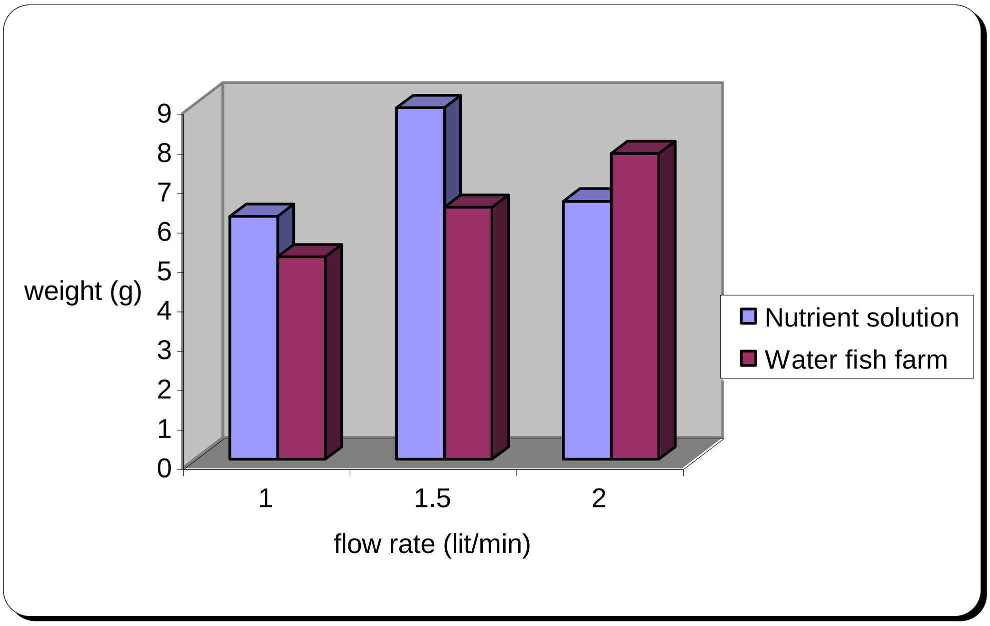

Fig. (4.7B): Effect of flow rate on dry weight of root

4.5.2.2. Effect of length of gully on fresh and dry of root:

Table (4.9) and figures (4.8A and B) show the effect of length of gully on fresh and dry weight of root production of lettuce plants at the end of growing period. The fresh weight was increased with increasing the length of gully at 2 to 3 m. The fresh weight increased from 88.10 to 94.98 $g.plant^{-1}$ (7.24%) in nutrient solution and increased from 86.98 to 89.97 $g.plant^{-1}$ (3.32%) in water discharged from the fish farm. The dry weight was increased with increasing the length of gully at 2 to 3 m in the nutrient solution. The dry weight increased from 6.49 to 8.14 $g.plant^{-1}$ (20.27%). While, the dry weight was decreased with increasing the length of gully at 2 to 3m in water discharged from the fish farm. The dry weight decreased from 7.00 to 5.61 $g.plant^{-1}$ (19.86%). However, the fresh weight was decreased with increasing the length of gully at 3 to 4 m. The fresh weight decreased from 94.98 to 85.74 $g.plant^{-1}$ (9.73%) in nutrient solution and decreased from 89.97 to 82.23 $g.plant^{-1}$ (8.60%) in water discharged from the fish farm. The dry weight was decreased with increasing the length of gully at 3 to 4 m in the nutrient solution. The dry weight decreased from 8.14 to 6.98 $g.plant^{-1}$ (14.25%). While, the dry weight was increased with increasing the length of gully at 3 to 4 m in water discharged from the fish farm. The dry weight increased from 5.61 to 6.44 $g.plant^{-1}$ (12.89%).

Table (4.9): Effect of length of gully on fresh and dry weight of root

Nutrient solution						Water fish farm					
2 m		3 m		4 m		2 m		3 m		4 m	
fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry	fresh	dry
86.10	6.49	94.98	8.14	85.74	6.98	86.98	7.00	89.97	5.16	82.23	6.44

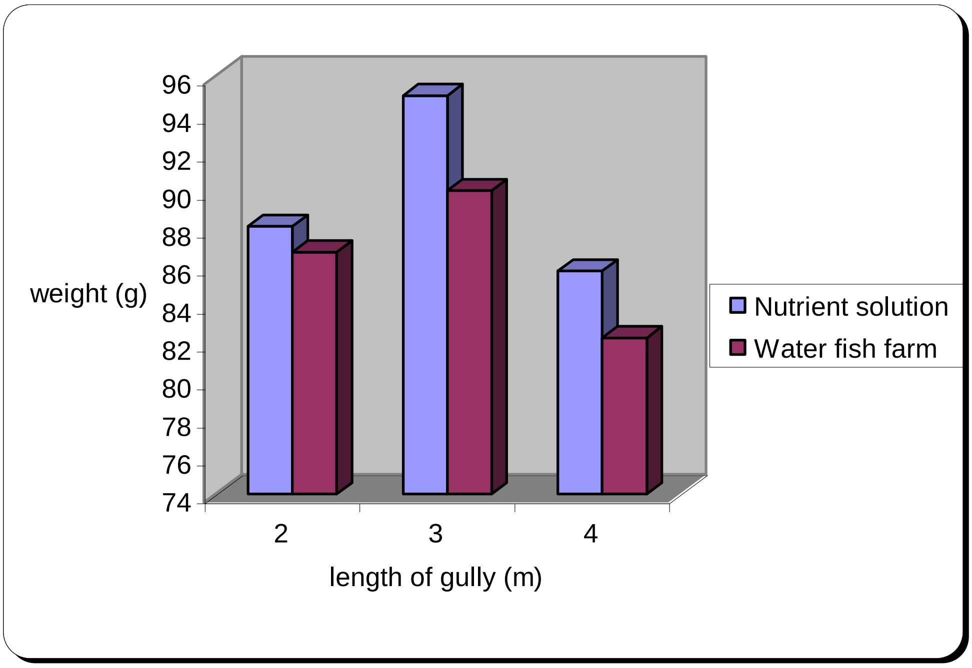

Fig. (4.8A): Effect of length of gully on fresh weight of root

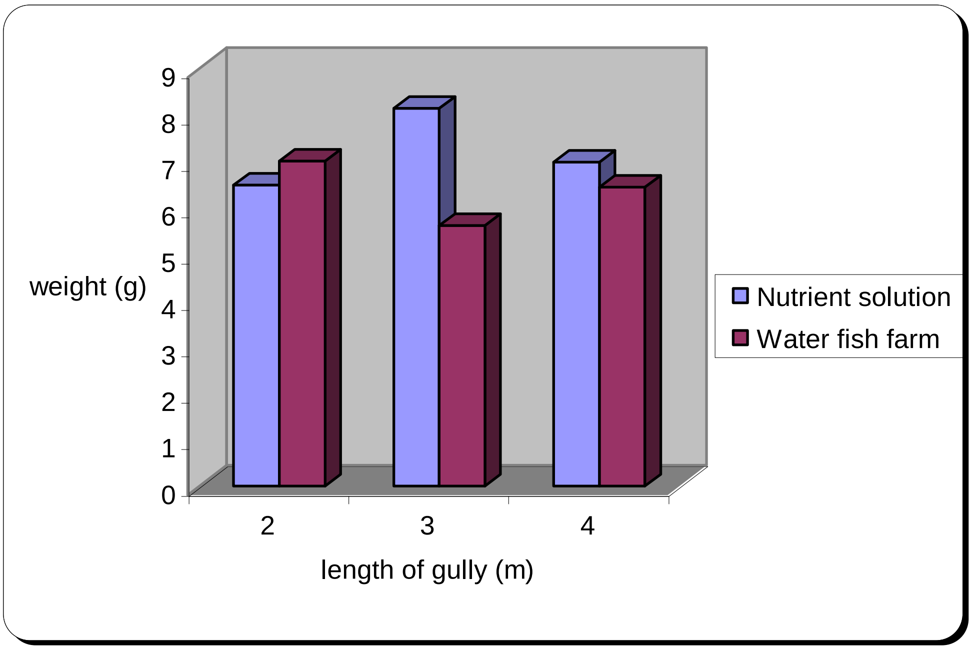

Fig. (4.8B): Effect of length of gully on dry weight of root

4.6. Crop loss:

4.6.1. Effect of flow rate on crop loss:

Table (4.12) and figure (4.11) show the effect of flow rate on crop loss (%) at the end of growing period. The crop loss was decreased with increasing the flow rate at 1 to 1.5 lit.min^{-1}. The loss decreased from 7.45% to 7.20% in nutrient solution and decreased from 9.48% to 9.45% in water discharged from the fish farm. However, the loss was increased with increasing the flow rate at 1.5 to 2 lit.min^{-1}. The loss increased from 7.20% to 8.43% in nutrient solution and increased from 9.45% to 10.45% in water discharged from the fish farm. These results were in agreement with **Prince et al. (1981)** found that the crop loss was decreased the flow rate at 80 to 100 ml.s^{-1}.

Table (4.12): Effect of flow rate on crop less (%)

Nutrient solution			Water fish farm		
1 lit/min	1.5 lit/min	2 lit/min	1 lit/min	1.5 lit/min	2 lit/min
7.45	7.20	8.43	9.48	9.45	10.45

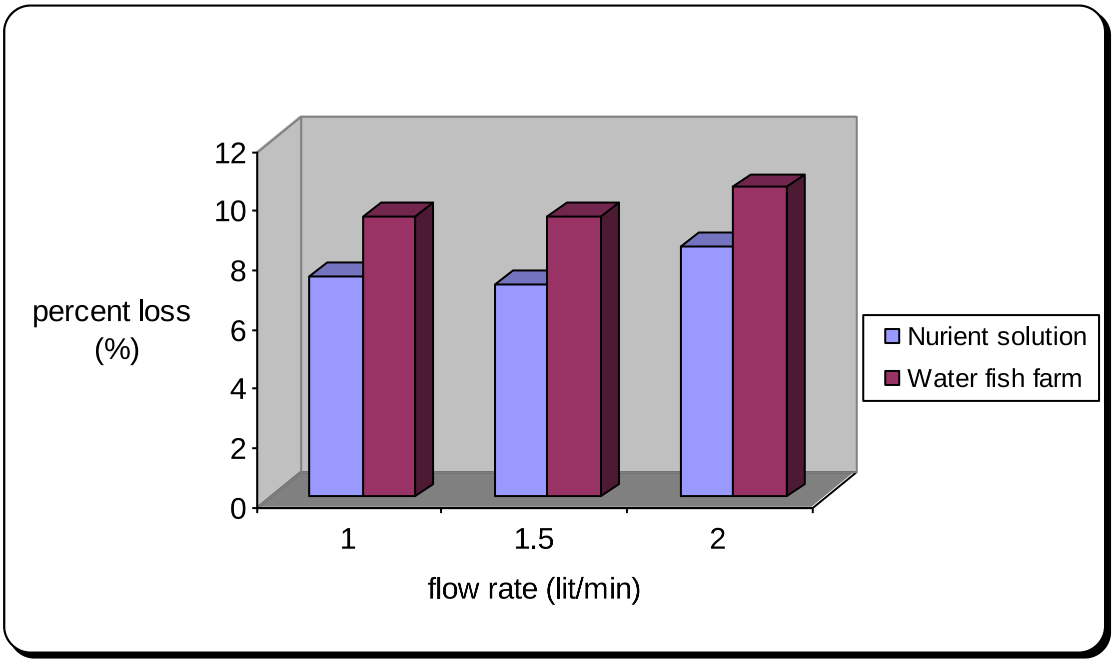

Fig. (4.11): Effect of flow rate on crop loss

4.6.2. Effect of length of gully on crop loss:

Table (4.13) and figure (4.12) show the effect of length of gully on crop loss (%) at the end of growing period. The loss was decreased with increasing the length of gully in nutrient solution. The loss decreased from 9.24% to 5.21% at 2 and 4 m length of gully, respectively. While, the loss was decreased with increasing the length of gully at 2 to 3 m in water discharged from the fish farm. The loss increased from 9.66% to 12.48%. However, the loss was decreased with increasing the length of gully at 3 to 4 m in water discharged from the fish farm. The loss decreased from 12.48% to 7.25%.

Table (4.13): Effect of length of gully on crop loss (%)

Nutrient solution			Water fish farm		
2 m	3 m	4 m	2 m	3 m	4 m
9.24	8.63	5.21	9.66	12.48	7.25

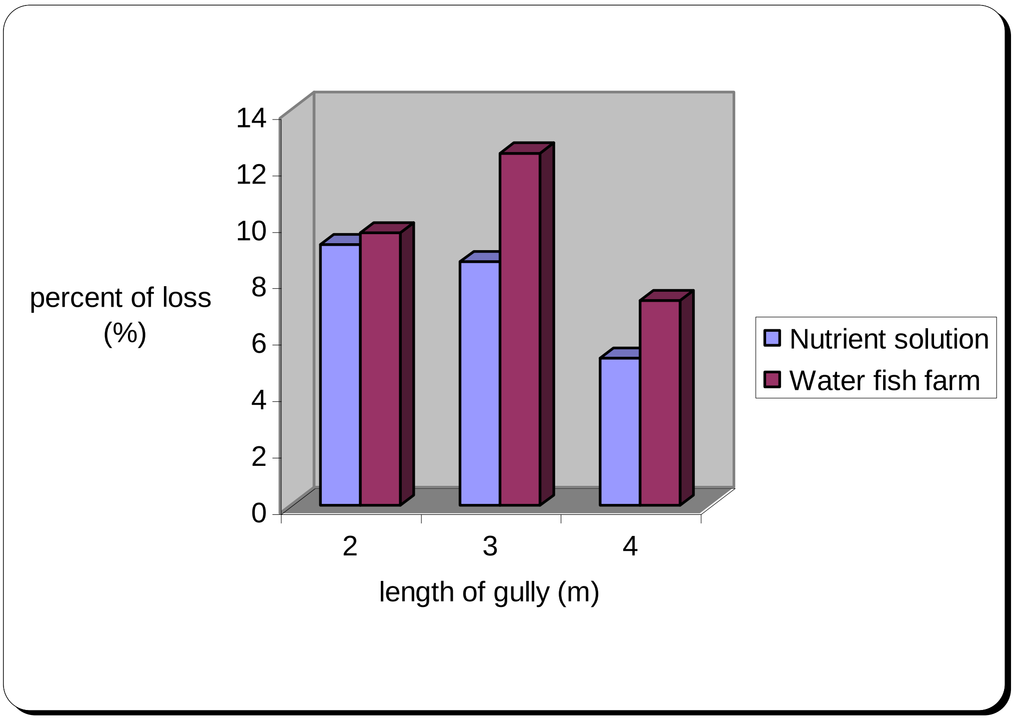

Fig. (4.12): Effect of length of gully on crop loss

4.7. Total nutrients uptake:

4.7.1. Effect of flow rate on total nutrients uptake:

Tables (4.14) and figures (4.13A, B, C, D, and E) show the effect of flow rate on N, P, K, Ca and Mg uptake, respectively by lettuce plants at the end of growing period was estimated from the dry weight of the entire plant as mg plant^{-1}. The total nutrients uptake were decreased with increasing the flow rate. For example, N uptake decreased from 274.34 to 240.52 mg.plant^{-1} (12.33%) in nutrient solution and decreased from 168.27 to 152.42 mg.plant^{-1} (8.23%) in water discharged from the fish farm at 1 and 2 lit min^{-1} flow rate, respectively.

The variation of nutrients uptake by root is attributed to nutrient concentration close to its surface, diffusion of nutrients through the root surface, interactions between nutrients and selectivity. It could be indicated that nutrient solution use was more efficient as compared with water discharged from the fish farm under different flow rate. These results were in agreement with **(Adams, 1992)**.

Table (4.14): Effect of flow rate on nutrients uptake.

element	Nutrient Solution			Water Fish Farm		
	1 lit min^{-1}	1.5lit min^{-1}	2 lit min^{-1}	1 lit min^{-1}	1.5 lit min^{-1}	2 lit min^{-1}
N	154.42	162.09	168.27	240.52	254.36	274.34
P	29.06	31.15	37.43	45.71	47.96	51.22
K	193.53	195.95	199.68	396.24	399.75	404.17
Ca	52.88	55.65	58.74	121.96	125.51	128.67
Mg	179.41	182.19	185.94	245.18	247.80	253.64

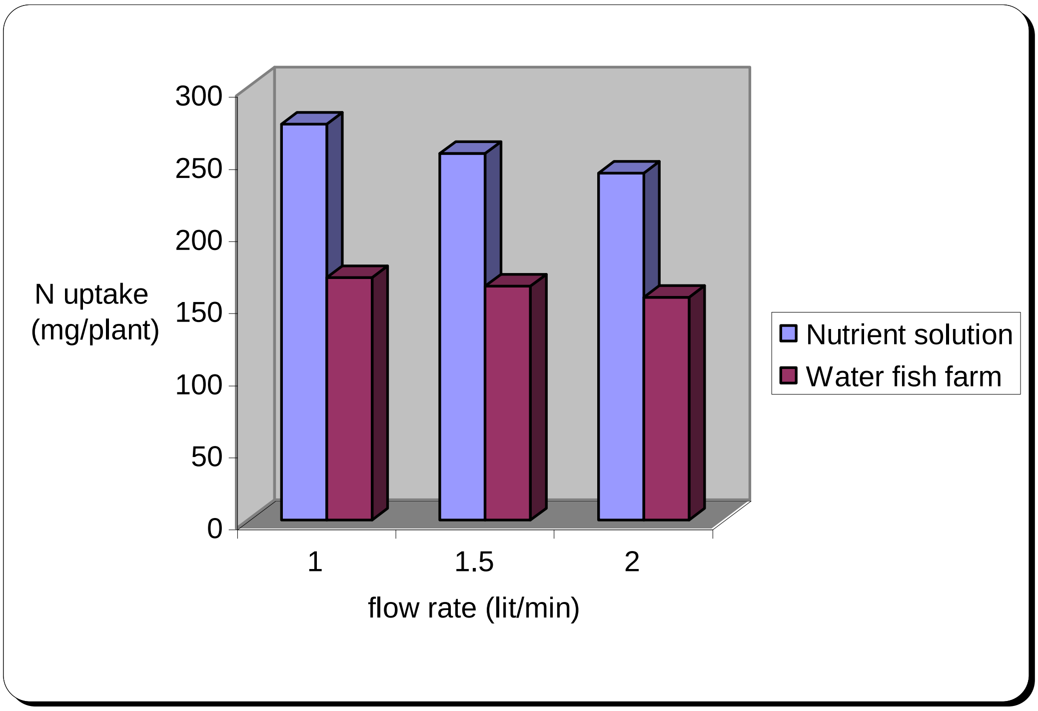

Fig. (4.13A): Effect of flow rate on N uptake

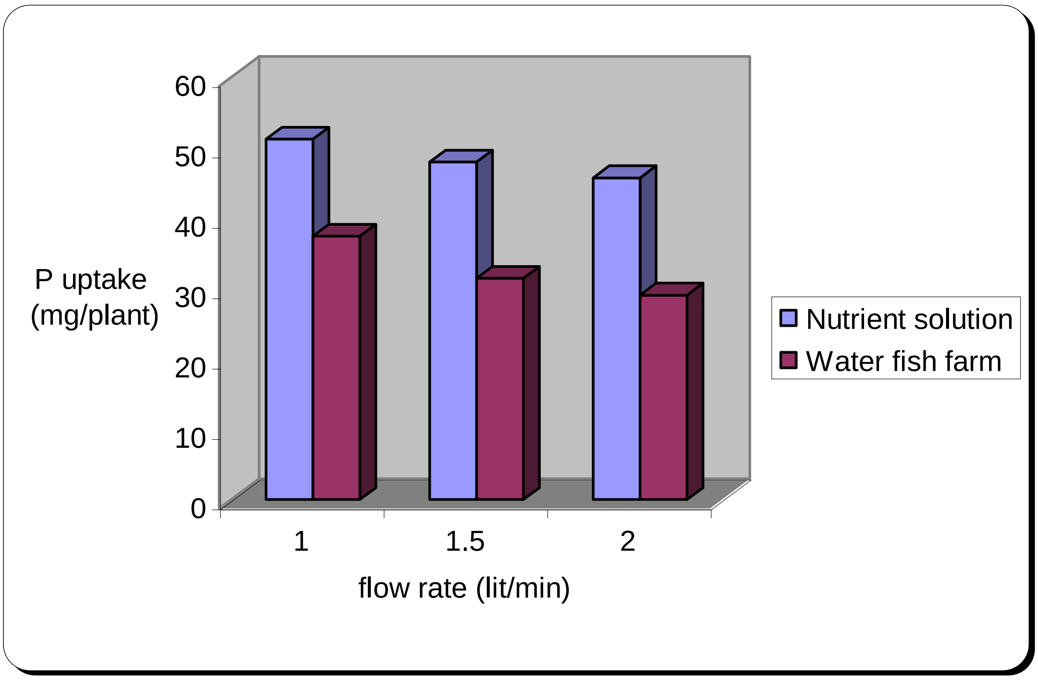

Fig. (4.13B): Effect of flow rate on P uptake

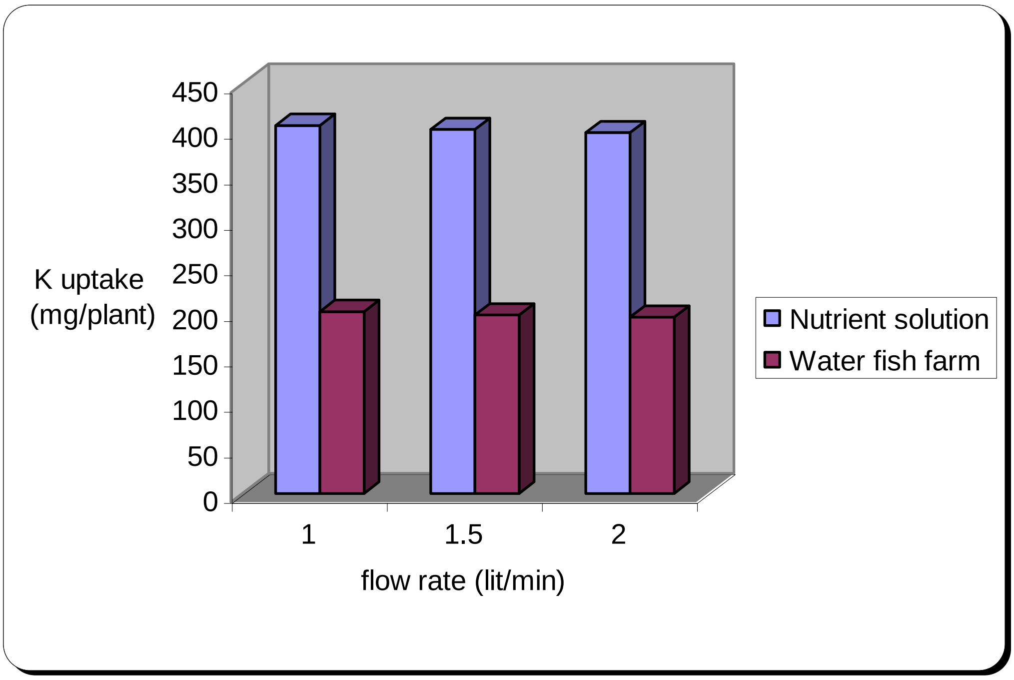

Fig. (4.13C): Effect of flow rate on K uptake

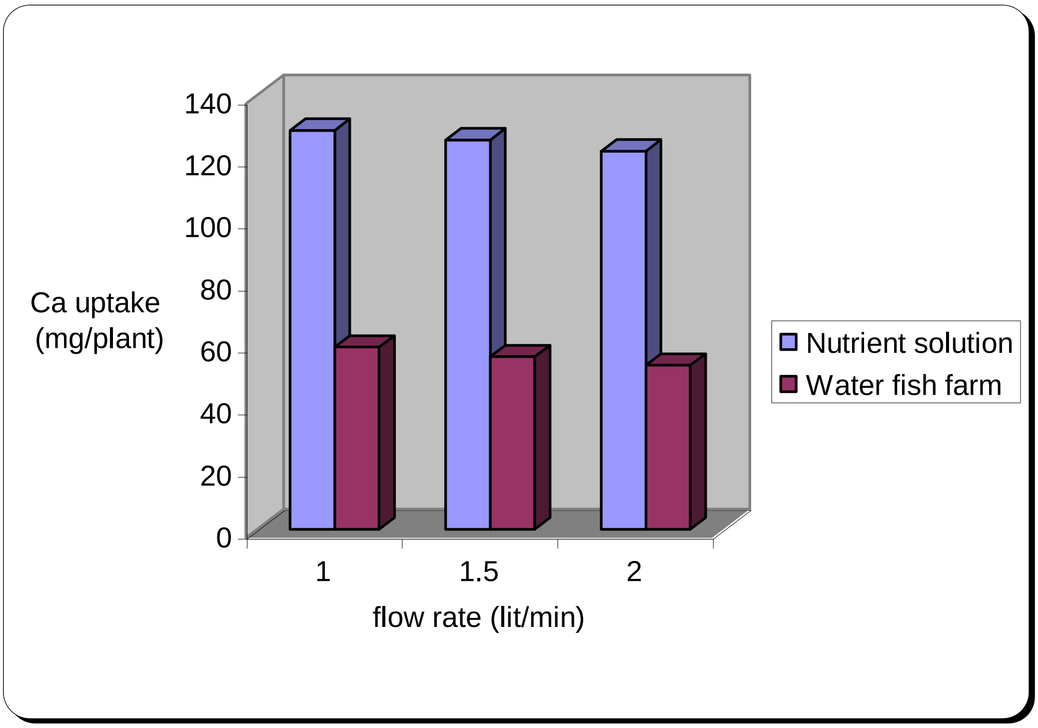

Fig. (4.13D): Effect of flow rate on Ca uptake

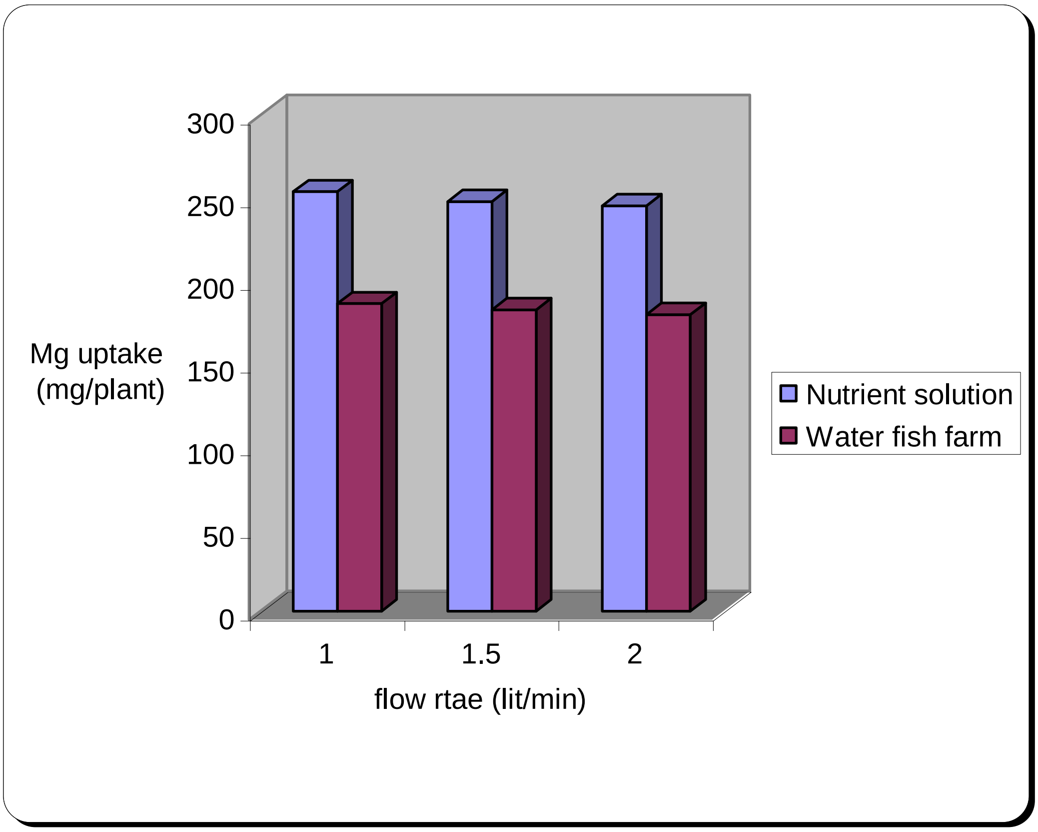

Fig. (4.13E): Effect of flow rate on Mg uptake

4.7.2. Effect of length of gully on total nutrients uptake:

Tables (4.15) and figures (4.14A, B, C, D and E) show the effect of length of gully on N, P, K, Ca and Mg uptake, respectively by lettuce plants at the end of growing period was estimated from the dry weight of the entire plant as mg plant^{-1}. The total nutrients uptake were decreased with increasing the length of gully. For example, N uptake decreased from 260.81 to 252.58 mg.plant^{-1} (3.16%) in nutrient solution and decreased from 165.86 to 156.54 mg.plant^{-1} (5.62%) in water discharged from the fish farm at 2 and 4 m length of gully, respectively.

The variation of nutrient uptake by root is attributed to nutrient concentration close to its surface, diffusion of nutrients through the root surface, interactions between nutrients and selectivity. It could be indication that nutrient solution use was more efficient as compared with water discharged from the fish farm under different length of gully.

Table (4.15): Effect of length of gully on nutrients uptake.

element	Nutrient Solution			Water Fish Farm		
	2 m	3 m	4 m	2 m	3 m	4 m
N	156.54	162.37	165.86	252.58	255.84	260.81
P	28.97	31.85	32.83	45.425	47.71	51.77
K	192.91	196.12	200.13	395.77	399.55	404.84
Ca	51.41	56.01	59.86	120.01	125.56	130.58
Mg	178.44	182.29	186.82	243.41	249.27	253.93

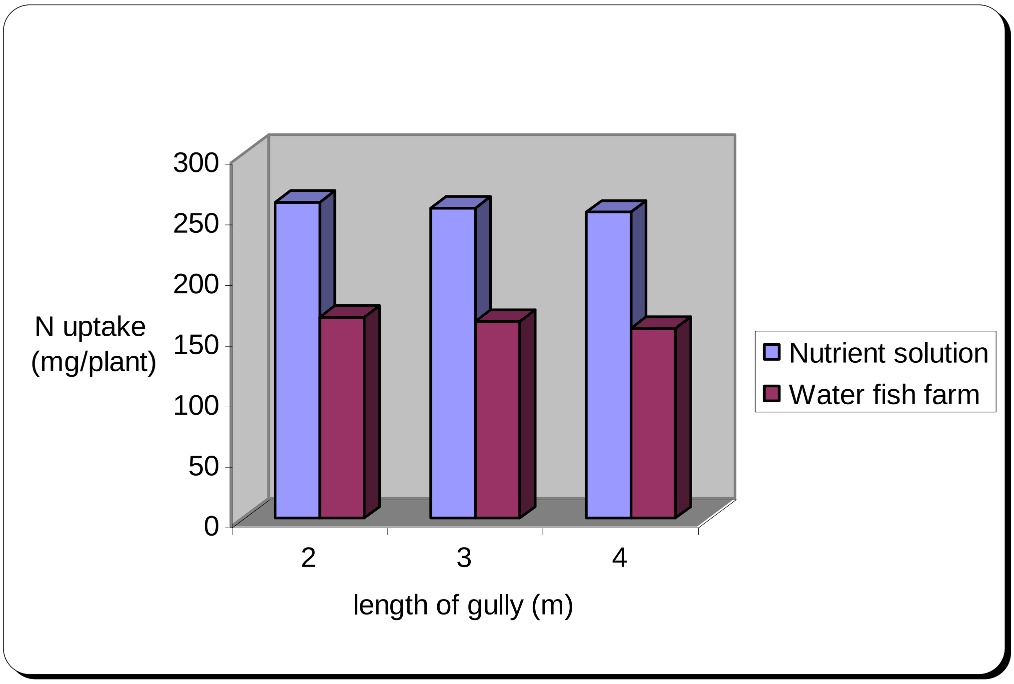

Fig. (4.14A): Effect of length of gully on N uptake

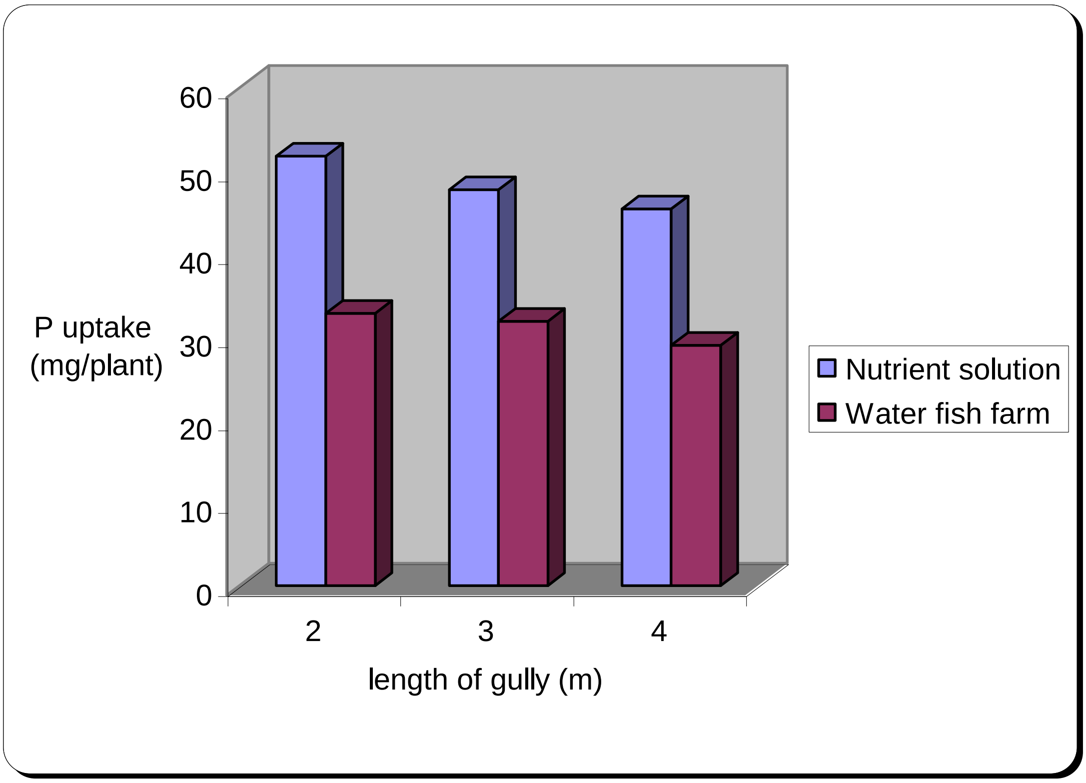

Fig. (4.14B): Effect of length of gully on P uptake

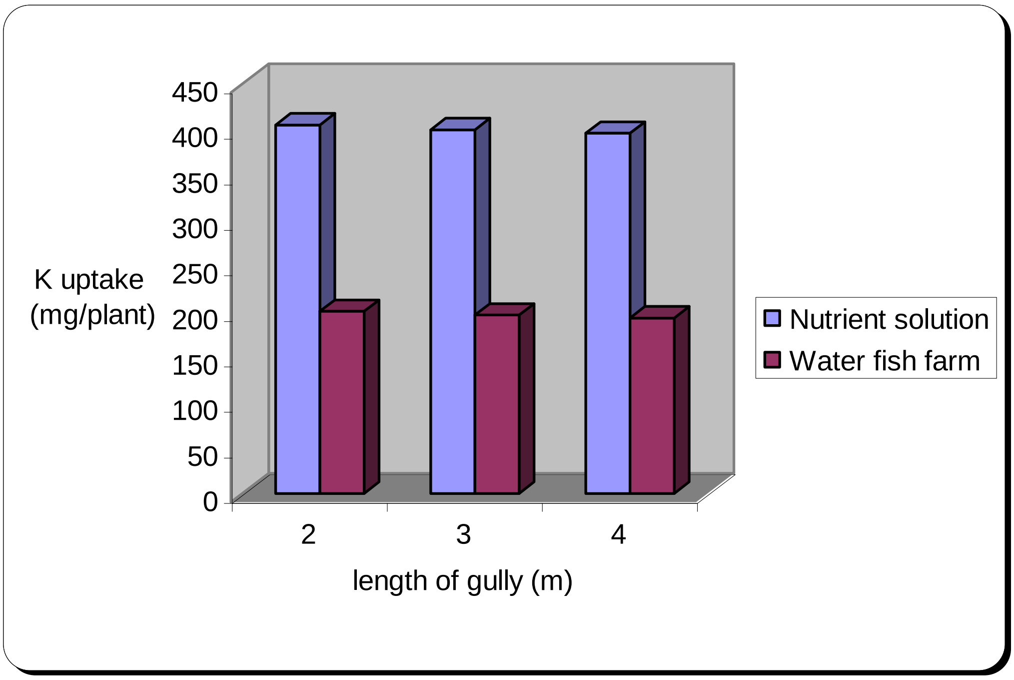

Fig. (4.14C): Effect of length of gully on K uptake

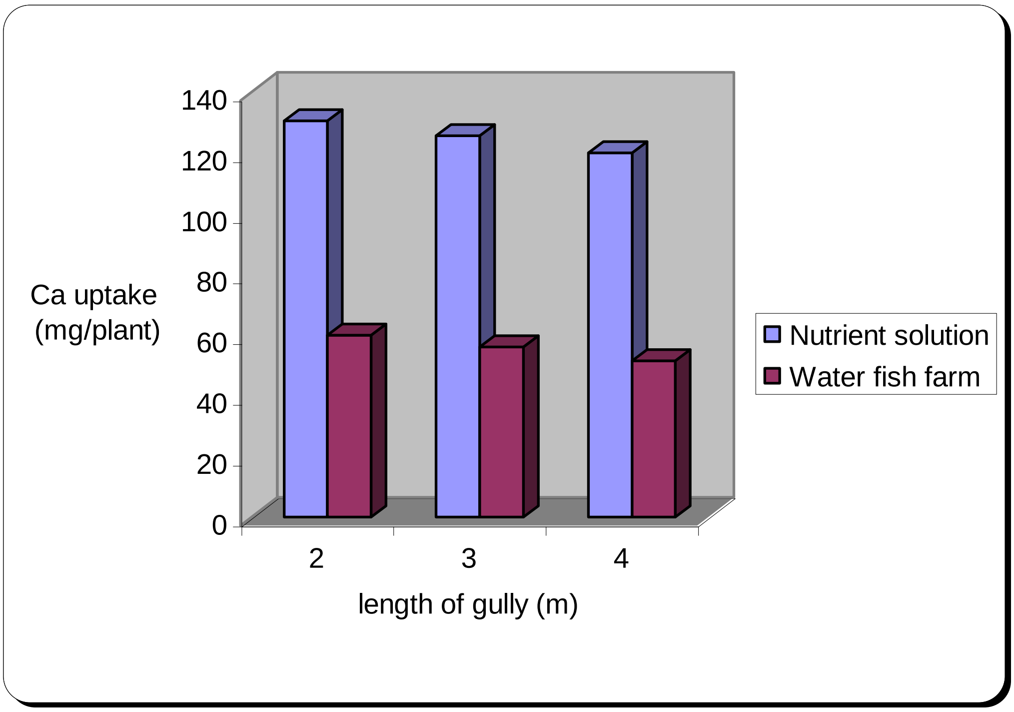

Fig. (4.14E): Effect of length of gully on Ca uptake

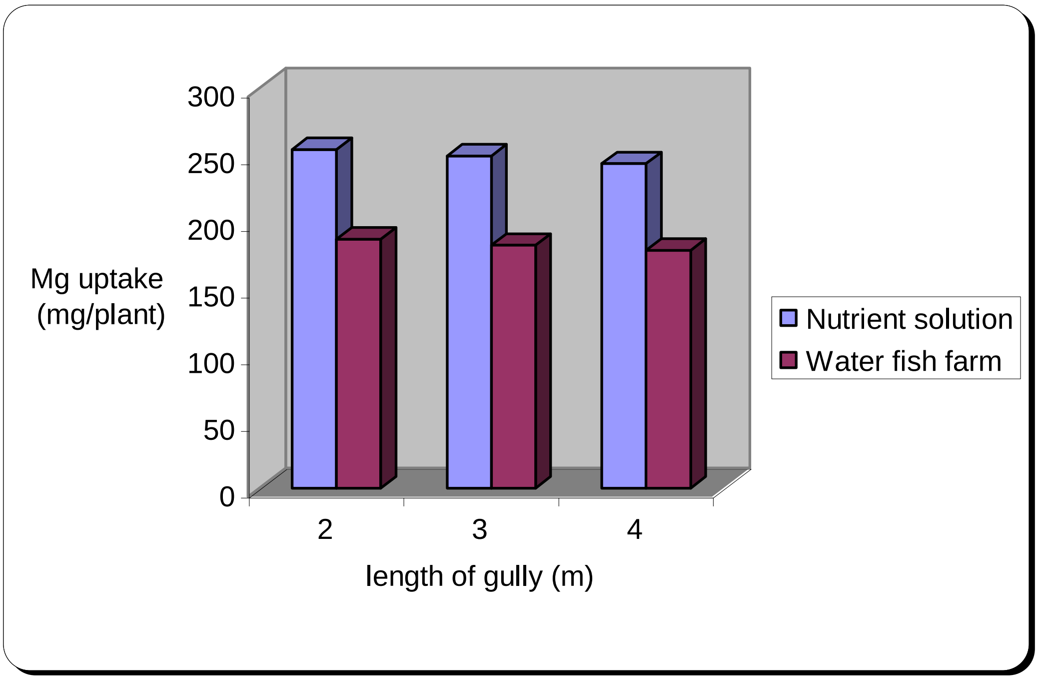

Fig. (4.14D): Effect of length of gully on Mg uptake

4.7.3. Nitrate Uptake:

4.7.3.1. Effect of flow rate on No_3 Uptake:

Table (4.16) and figure (4.15) show the effect of flow rate on No_3 uptake by lettuce plants at the end of growing period was estimated from the dry weight of the entire plant as mg.plant^{-1}. The No_3 was decreased with increasing the flow rate. The No_3 decreased from 239.78 to 221.65 mg.plant^{-1} (7.56%) in nutrient solution and decreased from 111.31 to 100.86 mg.plant^{-1} (9.39%) in water discharged from the fish farm at 1 and 2 lit min^{-1} flow rate, respectively.

Table (4.16): Effect of flow rate on No_3 uptake as mg plant^{-1}

Nutrient solution			Water fish farm		
1 lit/min	1.5 lit/min	2 lit/min	1 lit/min	1.5 lit/min	2 lit/min
239.78	224.56	221.65	111.31	108.92	100.86

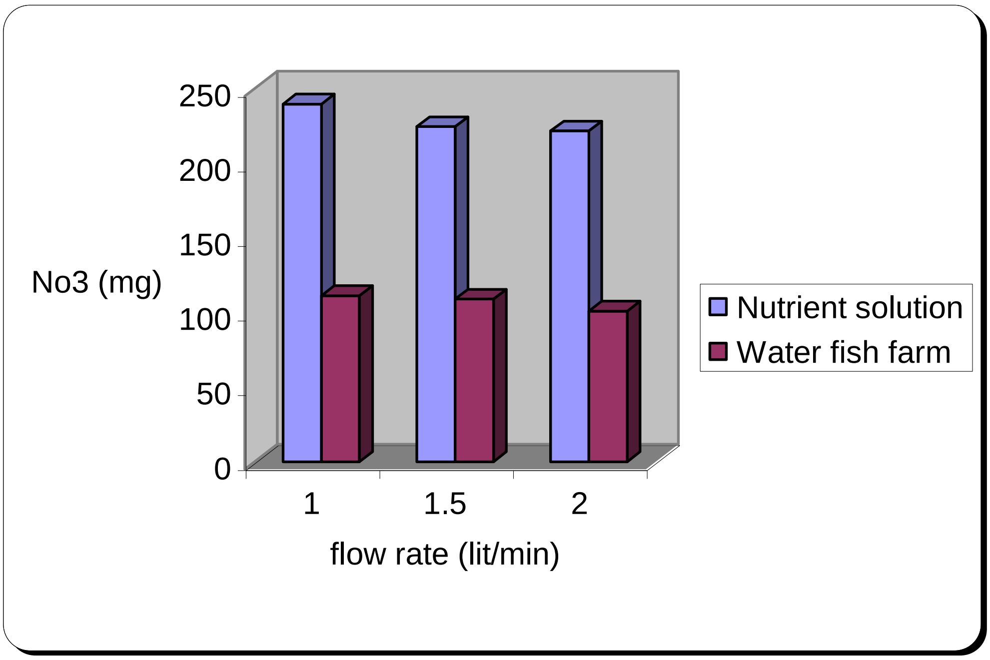

Fig. (4.15): Effect of flow rate on No_3 uptake.

4.7.3.2. Effect of length of gully on No_3 Uptake:

Table (4.17) and figure (4.16) show the effect of length of gully on No_3 uptake by lettuce plants at the end of growing period was estimated from the dry weight of the entire plant as mg plant^{-1}**.** The No_3 was decreased with increasing the length of gully. The No_3 decreased from 244.11 to 210.60 mg.plant^{-1} (13.73%) in nutrient solution and decreased 114.18 to 101.19 mg.plant^{-1} (11.38%) in water discharged from the fish farm at 2 and 4 m length of gully, respectively.

Table (4.17): Effect of length of gully on No_3 uptake as mg plant^{-1}

Nutrient solution			Water fish farm		
2 m	3 m	4 m	2 m	3 m	4 m
244.11	231.28	210.60	114.18	105.72	101.19

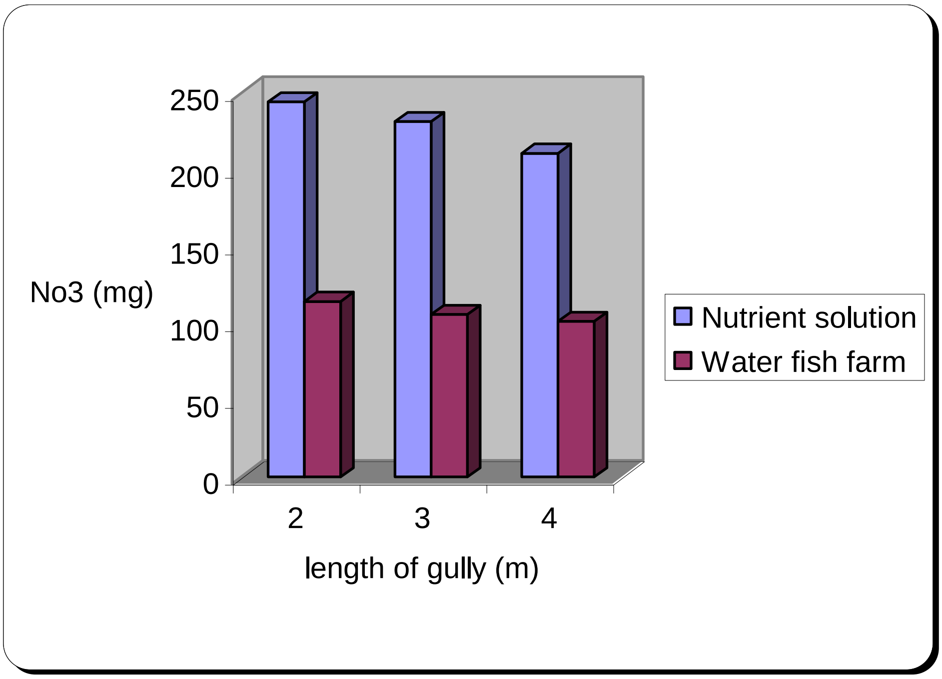

Fig. (4.16): Effect of length of gully on No_3 uptake.

4.7.4. No_3/ protein ratio:

4.7.4.1. Effect of flow rate on No_3/ protein ratio:

Table (4.18) and figure (4.17) show the effect of flow rate on No_3/protein ratio. The No_3/protein ratio was increased with increasing the flow rate. The No_3/protein ratio increased from 13.98 to 14.13% in nutrient solution and increased from 10.58 to 10.99% in water discharged from the fish farm at 1 and2 lit.min^{-1} flow rate, respectively.

Table (4.18): Effect of flow rate on No_3/protein ratio.

Nutrient solution			Water fish farm		
1 lit/min	1.5 lit/min	2 lit/min	1 lit/min	1.5 lit/min	2 lit/min
13.98	14.13	14.74	10.58	10.98	10.99

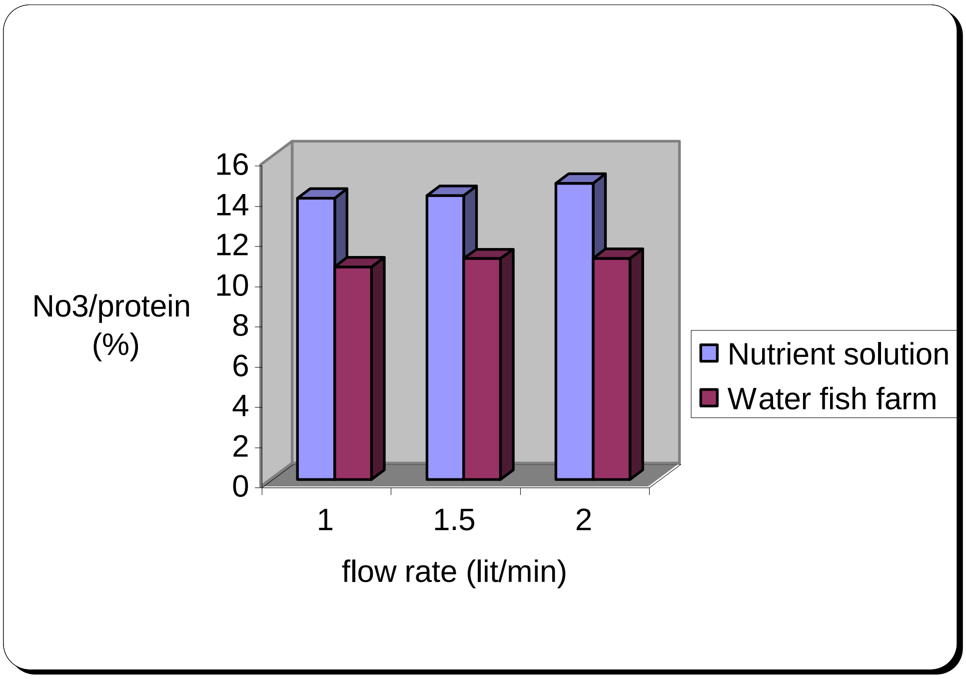

Fig. (4.17): Effect of flow rate on No_3/protein ratio.

4.7.4.2. Effect of length of gully on No_3/ protein ratio:

Table (4.19) and figure (4.18) show the effect of length of gully on No_3/protein ratio. The No_3/protein ratio was decreased with increasing the flow rate. The No_3/protein ratio decreased from 14.98 to 13.34% in nutrient solution and decreased from 11.24 to 10.34% in water discharged from the fish farm at 2 and 4 m length of gully, respectively.

Table (4.19): Effect of length of gully on No_3/protein ratio.

Nutrient solution			Water fish farm		
2 m	3 m	4 m	2 m	3 m	4 m
14.98	14.46	13.34	11.24	10.73	10.34

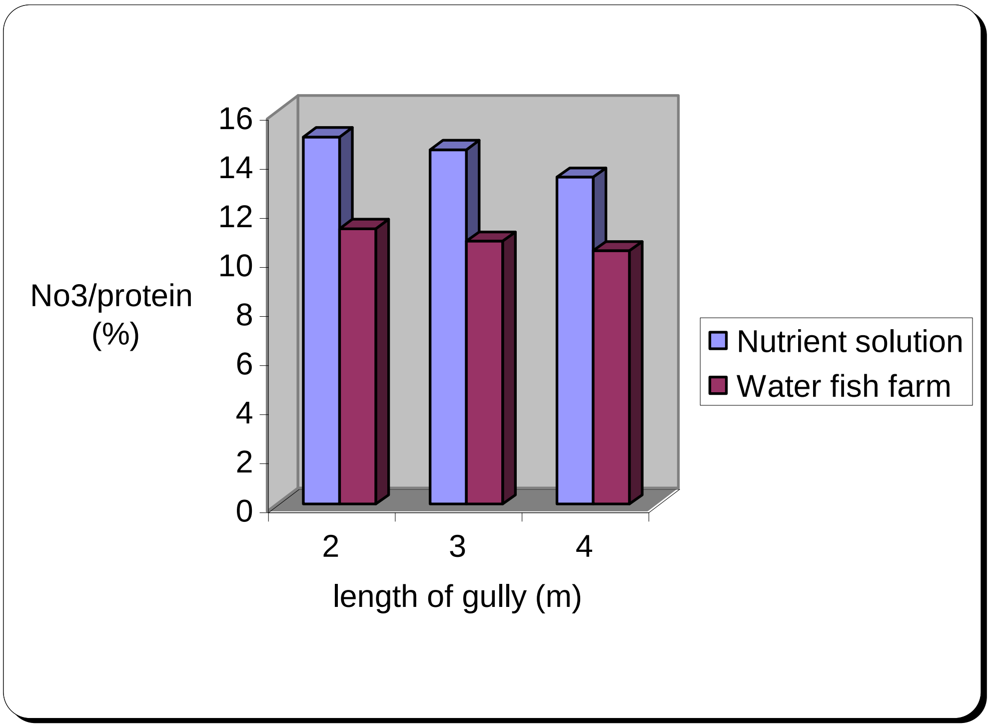

Fig. (4.18): Effect of length of gully on No_3/protein ratio.

4.8. Economical study:

4.8.1. Economics of nutrient solution system:

4.8.1.1. Economics of the system:

Table (4.20) shows the price of components used in the system consists of 500 plants.

Table (4.20): The price of components used in the nutrient solution system consists of 500 plants.

The components	Price (L. E.)
1- Irrigation Pump	350
2- Fram Iron	170
3- Plastic Sheet	50
4- Foam Boards	105
5- Fitting and Valves	88
6- Solution Tank	100
7- Pots	30
8- Peatmoss	35
Total	928

4.8.1.2. Economics of nutrient solution:

Nutrient solution analysis in system consists of 500 plants need approximately 0.662 Kg calcium nitrate, 0.505 Kg potassium nitrate, 0.137 Kg potassium dihydrogen phosphate and 1.353 Kg magnesium sulphate.

The prices of the pure chemicals which make of nutrient solution are 9.95, 22.75, 1.20 and 10.85 L.E. for calcium nitrate, potassium nitrate, potassium dihydrogen phosphate and magnesium sulphate, respectively. The total price of chemicals are approximately 44.75 L.E.

The total price for prodution of 500 plants in nutrient solution system equal 972.75 L.E.

4.8.2. Economics of water fish farm system:

Table (4.21) shows the price of components used in the system consists of 500 plants.

Table (4.21):The price of components used in the water fish farm system consists of 500 plants.

The components	Price (L. E.)
1- Irrigation Pump	350
2- Fram Iron	170
3- Plastic Sheet	50
4- Foam Boards	105
5- Fitting and Valves	88
6- Pots	30
7- Peatmoss	35
Total	828

The total price for prodution of 500 plants in water fish farm system equal 828 L.E.

5- SUMMARY AND CONCLUION

The main objectives of this research were to study to which extent the content of nutrients in water farming is sufficient for growing plants, determine the proportion of nitrogen that was taken up by plants to the total nitrogen content in the fish farm and the effect of this (nitrogen exit of fish farm) on reducing the costs of plant production which resulted in increasing the economical income under this study. Save the renewable water in fish farming (1-10% of the total quantity of its water) and using it in irrigating plants.

The experiment was carried out at El-Nenaiea Farm, Ashmon, El-Minufiya governorate. During 2006 season. To study the effect of source of nutrient, flow rate and length of gully on the following parameters: nutrient consumption, length of root, fresh and dry weight, crop loss, nutrients uptake and No_3/protein ratio.

The treatments under study are: source of nutrient (waste fish farm and stock nutrient solution), flow rate (1.0, 1.5 and 2.0 lit min^{-1}) and length of gully (2, 3 and 4 m).

The obtained results can be summarized as follows:

5.1. Nutrient Consumption:

There were changes in consumption of N, P, K, Ca and Mg during the growing period of lettuce. The nutrients consumption were decreased with increasing the flow rate and decreased with increasing the length of gully. The rate of nutrients consumption was more in nutrient solution than in waste fish farm. The highest values of plant consumption were found at a flow rate 1 lit min^{-1} and 2 m length of gully. The lowest values of plant consumption were found at a flow rate 2 lit min^{-1} and 4 m length of gully. The best treatment of nutrient consumption (the high value of fresh weight) was found with the flow rate 2 lit min^{-1} and 4 m length of gully.

5.2. The length of root:

The length of root was increased with increasing the flow rate and increased with increasing the length of gully. The rate of growth root was more in waste fish farm than in nutrient solution. The length of root tended to faviour high value of fresh weight which associated with the highest root length (20.00 cm).

5.3. Fresh and dry weight:

5.3.1. Fresh and dry weight of shoot:

The fresh and dry weight of shoot were increased with increasing the flow rate. The fresh and dry weight of shoot were decreased with increasing the length of gully at 2 to 3 m and increased with increasing the length of gully at 3 to 4 m. The fresh and dry weight of shoot were more in nutrient solution than in waste fish farm. The best treatment (the high value of fresh weight) was found with the flow rate 2 lit min^{-1} and 4 m length of gully.

5.3.2. Fresh and dry weight of root:

The fresh and dry weight of root were increased with increasing the flow rate at 1.0 to 1.5 lit min^{-1}and decreased with increasing the flow rate at 1.5 to 2.0 lit min^{-1}.While, the fresh and dry weight of root were increased with increasing the length of gully at 2 to 3 m and decreased with increasing the length of gully at 3 to 4 m.

5.3.3. Fresh and dry weight of unmarketable leaves:

The fresh and dry weight of unmarketable leaves were increased with increasing the flow rate and decreased with increasing the length of gully.

5.4. Crop Loss:

The crop loss was decreased with increasing the flow rate at 1.0 to 1.5 lit min^{-1} and increased with increasing the flow rate at 1.5 to 2.0 lit min^{-1}. The crop loss was decreased with increasing the length of gully in nutrient solution. While, the crop loss was increased with increasing the length of gully at 2 to 3 m and decreased with increasing the length of gully at 3 to 4 m in waste fish farm.

5.5. Total nutrient uptake:

The total nutrients uptake were decreased with increasing the flow rate and decreased with increasing the length of gully. The total nutrients uptake were more in nutrient solution than in waste fish farm.

5.6. Nitrate uptake:

The nitrate was decreased with increasing the flow rate and decreased with increasing the length of gully. The nitrate was more in nutrient solution than in waste fish farm.

5.7. No_3/protein ratio:

The No_3/protein ratio was increased with increasing the flow rate and decreased with increasing the length of gully. The No_3/protein ratio was more in nutrient solution than in waste fish farm.

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الملخص العربى

مقدمة

نتيجة للزيادة المضطردة فى السكان تتجه الدولة لاستخدام النظم الحديثة لزيادة الانتاج ومسايرة التقدم العالمى في نقل التكنولوجيا وخاصة فى مجال الانتاج الزراعي.وقد أظهرت الدراسات السابقة أن ري محاصيل الحقل بإستخدام مخرجات الأسماك يؤدى إلى زيادة كفاءة استخدام المياه كما يؤدى إلى انتاج محصول نامى بإستخدام نفس المياه فضلا عن إزالة مشاكل التخلص من فضلات الأسماك. وهذا ما يعرف بنظام Aquaponics.

Aquaponics هو عبارة عن التكامل بين الاستزراع السمكي Aquaculture وإنتاج النباتات بدون تربة Soilles Culture أو Hydroponics وفى هذا النظام تستهلك الأسماك الغذاء وتخرج الفضلات وهى عبارة عى آمونيا فتقوم البكتريا بتحويلها إلى نيتريت ثم إلى نترات. ونجد أن النسب الصغيرة من الأمونيا تعتبر سامة للأسماك. فحين أن النترات ليست سامة للأسماك ومع هذا فإن زيادتها عن حد معين تصيب متناول الأسماك بما يسمى بالتلوث بالنترات وتصيبه بمرض الميثومجلوبينيا وهو تحول لون الدم إلى اللون البنى فيصبح غير قادر على حمل الأكسجين إلى باقى أجزاء الجسم ولذلك يتم صرف نسبة معينة من المياه يوميا وإضافة مياه مكانها للمحافظة على المستوى الأمن صحيا من النترات ولذا يلجأ مستزرعى الأسماك بهذا النظام إلى إلحاق بزراعة النباتات بدون تربة وذلك لتوفير المياه التى يتم تغيرها واستغلال النترات الموجودة فى المياه التى يتم تغيرها يوميا.

وتقوم بكتريا Nitrosomonas بتحويل الأمونيا إلى نيتريت وتقوم بكتريا Nitrobacter بتحويل النيترت إلى نترات فيمتصها النبات ويعمل على نظافة المياه المعاد استخدامها مرة أخرى إلى أحواض الأسماك أى أن فضلات الأسماك التى تعتبر سامة بالنسبة للأسماك تعتبر غذاء بالنسبة للنبات. ويتم استخدام هذه المياه فى رى النباتات من خلال أحواض زراعة تمر بها المياه فتقوم النباتات بترشيحها قبل استخدامها مرة أخرى فى أحواض الأسماك.

الهدف من البحث:-

1- دراسة مدى كفاية العناصر الموجودة فى مياه المزرعة لتغذية النباتات وتحديد مقدار الاستفادة من الأسمدة النيتروجينية التى تخرج من مياه المزارع السمكية فى تغذية النباتات وأثر ذلك على تقليل تكلفة انتاج محصول النباتات مما يؤدى إلى زيادة العائد الاقتصادى من هذه الدراسة.

2- توفير كمية من المياه حيث يتم فى الاستزراع السمكى المكثف تغير حوالى من 1-10% من مياه الأحواض على أساس كمية النترات الموجودة.

تم إجراء هذه التجربة فى مزرعة النعناعية – مركز أشمون – محافظة المنوفية خلال موسم 2006 لدراسة تأثير مصدر المحلول المغذى, معدل تدفق المحلول المغذى, طول المجرى على بعض العوامل وهى معدل استهلاك العناصر من المحلول, طول الجذر, الوزن الطازج والوزن الجاف, الفاقد فى المحصول, الاستهلاك الكلى للعناصر, الاستهلاك الكلى للنترات, نسبة النترات للبروتين.

وكانت المعاملات هى: مصدر المحلول المغذى (المياه الخارجة من مزرعة الأسماك والمحلول المجهز صناعيا), معدل تدفق المحلول (1 – 1.5 – 2 لتر/دقيقة), طول المجرى (2 – 3 – 4 م).

ويمكن تلخيص النتائج المتحصل عليها كما يلى:-

1- معدل استهلاك العناصر:

كان هناك اختلافات فى استهلاك العناصر (نيتروجين – فوسفور – بوتاسيوم – كالسيوم – ماغنسيوم) أثناء نمو نباتات الخس, قل معدل استهلاك العناصر بزيادة التصرف وزيادة طول المجرى. كان معدل استهلاك العناصر فى معاملات المحلول المغذى المجهز أعلى من معدل استهلاك العناصر فى معاملات مياه المزرعة.كانت أعلى قيمة لاستهلاك العناصر عند معدل تدفق 1 لتر/د مع طول مجرى 2م, فحين ان اقل قيمة لاستهلاك العناصر عند معدل تدفق 2 لتر/د مع طول مجرى 4 م. وكانت أفضل معاملة لاستهلاك العناصر (عند أعلى قيمة للوزن الطازج) عند معدل تدفق 2 لتر/د مع طول مجرى 4 م.

2- طول الجذر:

زاد طول الجذر مع زيادة التصرف وزيادة طول المجرى, كان معدل نمو الجذور فى معاملات مياه المزرعة اكبر من معدل نمو الجذور فى معاملات المحلول المغذى المجهز. كان أفضل طول للجذر (عند أعلى قيمة للوزن الطازج) هو 20 سم طول.

3- الوزن الطازج والوزن الجاف:

3-1- الوزن الطازج والوزن الجاف للمجموع الخضرى:

زاد الوزن الطازج والوزن الجاف للمجموع الخضرى بزيادة التصرف وقل بزيادة طول المجرى من 2 إلى 3 م بينما زاد مع زيادة طول المجرى من 3 إلى 4 م. كان الوزن الطازج والوزن الجاف فى معاملات المحلول المجهز اكبر من الوزن الطازج والوزن الجاف فى معاملات مياه المزرعة. وكانت أفضل معاملة (عند أعلى قيمة للوزن الطازج) عند تصرف 2 لتر/د مع طول مجرى 4 م.

3-2- الوزن الطازج والوزن الجاف للمجموع الجذري:

زاد الوزن الطازج والوزن الجاف للمجموع الجذري بزيادة التصرف من 1 إلى 1.5 لتر/د وقل بزيادة التصرف من 1.5 إلى 2 لتر/د. وزاد بزيادة طول المجرى من 2 إلى 3 م وقل بزيادة طول المجرى من 3 إلى 4 م.

3-3- الوزن الطازج والوزن الجاف للأوراق الغير صالحة للتسويق:

زاد الوزن الطازج والوزن الجاف للأوراق الغير صالحة للتسويق بزيادة التصرف وقل بزيادة طول المجرى.

4- الفاقد فى المحصول:

قل الفاقد فى المحصول بزيادة التصرف من 1 إلى 1.5 لتر/د وزاد بزيادة التصرف من 1.5 إلى 2 لتر/د. وزاد الفاقد فى المحصول بزيادة طول المجرى من 2 إلى 3 م وقل بزيادة طول المجرى من 3 إلى 4 م.

5- الاستهلاك الكلى للعناصر:

قل الاستهلاك الكلى للعناصر بزيادة التصرف وبزيادة طول المجرى. كان الاستهلاك الكلى للعناصر فى معاملات المحلول المغذى المجهز اكبر من الاستهلاك الكلى للعناصر فى معاملات مياه المزرعة.

6- الاستهلاك الكلى للنترات:

قل الاستهلاك الكلى للنترات بزيادة التصرف وبزيادة طول المجرى. كان الاستهلاك الكلى للنترات فى معاملات المحلول المغذى اكبر من الاستهلاك الكلى للنترات فى معاملات مياه المزرعة.

7- نسبة النترات للبروتين:

زادت نسبة النترات للبروتين بزيادة التصرف وقلت بزيادة طول المجرى. كانت نسبة النترات للبروتين فى معاملات المحلول المغذى المجهز أعلى من نسبة النترات للبروتين فى معاملات مياه المزرعة.